Descriptions of Early Life History Stages of Selected Fishes: from the 3rd International Symposium on the Early Life History of Fishes & 8th Annual Larval Fish Conference

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DESCRIPTIONS OF EARLY LIFE HISTORY STAGES OF SELECTED FISHES: FROM THE 3RD INTERNATIONAL SYMPOSIUM ON THE EARLY LIFE HISTORY OF FISHES AND 8TH ANNUAL LARVAL FISH CONFERENCE, MAY 1984, UNIVERSITY OF BRITISH COLUMBIA, VANCOUVER, CANADA

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ABSTRACT

Kendall, A.W., Jr. and J.B. Marliave (editors). 1985. Descriptions of early life history stages of selected fishes: from the 3rd International Symposium on the Early Life History of Fishes and 8th Annual Larval Fish Conference, May 1984, University of British Columbia, Vancouver, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 1359: 82 p.

A collection of eight papers, most of which were presented as posters in Vancouver is included here.

Leslie, J.K., and J.F. Gorrie. Distinguishing features for separating protolarvae of three species of esocids.
Minton, A.L., D.V. Osteen, and D.E. Snyder. Description of larval pirate perch, Aphredoderus sayanus (Gilliams), from the Savannah River.
Simon, T.P. Larval development of the cypress darter Etheostoma proeliare.
Snyder, D.E., and S. Ochman. Larvae and juveniles of Cottus ricei and sympatric Cottidae.
Marliave, J.B., S.K. Todd, and A.W.A. Baker. Larvae of the manacled sculpin, Synchirus gilli (Cottidae).
Moser, H.G., E.M. Sandknop, and D.A. Ambrose. Larvae and juveniles of aurora rockfish, Sebastes aurora, from off California and Baja California.
Stahl-Johnson, K.L. Descriptive characteristics of reared Sebastes caurinus and S. auriculatus larvae.
John, H.-Ch., and Ch. Karrer. The larval development of Schedophilus medusophagus Cocco 1839 (Teleostei, Perciformes).

These papers represent descriptions of a wide variety of taxa, and the authors present them in a variety of styles. The editors tried only to assure that each was scientifically acceptable, and did not restrict the format of presentation. Thus the reader can find information on the development of several fishes, and also compare several means of presenting such information.

Résumé

Le présent document comprend huit présentations dont la plupart ont fait l'objet d'une séance d'affichage au cours d'une conférence tenue à Vancouver.

Ces présentations, de styles variés, constituent des descriptions d'une grande variété de taxons. Les rédacteurs ne sont assurés que chacune était scientifiquement acceptable et ils ne se sont pas limités à une seule disposition. Le lecteur trouvera donc de l'information sur le développement de plusieurs poissons et pourra comparer plusieurs méthodes de présentation de telles données.

Distinguishing features for separating protolarvae of three species of esocids. Leslie, J.K., and J.F. Gorrie, Great Lakes Fisheries Research Branch, Burlington, Ontario.

INTRODUCTION

Concern with information gaps in the taxonomy of Great Lakes larval fish (Boreman 1976) led to the assignment of grass pickerel, Esox americanus vermiculatus LeSueur, and muskellunge, E. masquinongy Mitchill, to the highest priority rating for descriptions of eggs and larval stages. Subsequently, Buynak and Mohr (1979), described and illustrated larval muskellunge and northern pike, E. lucius Linnaeus, from Pennsylvania, in areas adjacent to the Great Lakes watershed. Information gaps, in varying degrees, remain in the taxonomy of these and other esocid species, especially grass pickerel. The purpose of the present paper is to provide developmental characteristics and illustrations that complement those in previous studies, thereby aiding in the taxonomic separation of three sympatric species, i.e., grass pickerel, northern pike, and muskellunge. This paper deals solely with the protolarval phase (Snyder 1976).

MATERIALS AND METHODS

Adult grass pickerel were caught on March 14, 1983, in a hoop net in Twenty Mile Creek (5.9°C), near Hamilton, Ontario, and brought to the laboratory. Fish were immediately artificially spawned, and fertilized eggs were incubated at 9°C. Adult northern pike were caught on March 16, 1983, in the same locale at 7.8°C, and the eggs were artificially spawned and fertilized on site, then brought to the laboratory, where they were incubated at constant temperature (15°C). Glass 30 L aquaria were used in an aired, closed system. Hatching both of grass pickerel and northern pike occurred on March 26, 1983, (10-12 d post-fertilization). Several hundred eggs and five to twenty larvae were frequently (1-3 d) removed and preserved with Davidson's B (Henderson 1963). Muskellunge larvae were obtained in May, 1981, and May 1982, from facilities at Deer Lake Hatchery (Ontario Ministry of Natural Resources), near Havelock, Ontario, and fixed with 10% buffered formalin, then preserved 4-6 wk later with Davidson's B.

Linear measurements of body components (Table 1), which were of the left side of each fish, had an accuracy of +/- 0.02-0.1 mm (depending upon size of the object), using a calibrated Model M5 Wild dissecting microscope. The diameter (random axis) of eggs and oil globules was measured with a compound microscope. Body components measured included total (TL) and standard length, which are, respectively, anterior-most point of head to tip of caudal fin and to the posterior extremity of notochord or hypurals; head length, the linear distance between anterior margin of head to base of pectoral fin in early stages, then to cleithrum; orbit, the horizontal diameter of the orbital rim; preanal length, anterior-most of head to centre of anus; snout to ventral fin fold, anterior-most of head to junction of fin fold and yolk sac; orbit to anus, posterior rim of orbit to centre of anus; yolk sac to anus, posterior margin of yolk sac to centre of anus; yolk sac, anterior to posterior extension of yolk sac at attachment to body.

Myomere counts excluded the first preanal, deltoid-shaped segment (Lippson and Moran 1974), whose exact anterior limit was often difficult to discern. The final preanal myomere is that which is transected at its ventral edge by an extended vertical line from the posterior margin of the anus; the terminal, incomplete myomere was included in the postanal count. A camera lucida was used to assist in illustrating specimens, with details added free-hand. All descriptions, measurements, and sketches were of fish that had been preserved from 2 to 24 months.

RESULTS AND DISCUSSION

DIAGNOSIS

The combination of habitat type and low water temperature selected by esocids for spawning is used by few species of Great Lakes fish. Esocids spawn in shallow water, in marshes, and floodplains shortly after most ice has melted. At hatch, larvae are characterized by an elongate body with pronounced, yellow or amber egg-shaped yolk sac, over which the head decurves. The preanal length ranges from 68 to 76% TL, and the dorsal fin fold originates at the nape and is continuous with the ventral fin fold, which attaches at the posterior margin of the yolk sac. The notochord extends closer to the end of the fin fold and the end of the fin fold is more pointed in esocids than in higher fishes. The larvae have an obvious, body length, hypaxial stripe of melanophores. Prior to swim-up, larvae are sessile, either lying on their side on the substrate, or vertically attached by their adhesive glands to vegetation. Post swim-up larvae are typically reclusive in or near aquatic vegetation.

DESCRIPTIONS

Esox americanus vermiculatus (grass pickerel)

Ripe ovarian eggs (N = 72) range: 2.5-3.0 mm, (mean = 2.7 mm); fertilized preserved eggs (N = 400), range: 2.5-3.0 mm; (mean = 2.8 mm).

1. Hatch to 7.5 mm. Newly hatched larvae (Fig. 1 A-C) ranged from 5.8 to 6.6 mm (mean = 6.1 mm); body: elongate, dominated by large, slightly oval yolk sac, over which head is decurved (Fig. 1 A); oil globules in small groups of ca. 4-6, located surficially throughout the yellow yolk, mainly laterally and ventrally; urostyle extended to tip of caudal fin fold; eye: dominant, with choroid fissure; paired, crescent-shaped adhesive glands, with minute papillae, adjacent and anterior to orbits (Fig. 1 C); mouth:

inferior, incomplete; pectoral fin buds present; anus: thin, decurved, obtuse, extended to margin of fin fold (Fig. 1 A,C). At ca. 6.0 mm, standard length: 98% TL; orbit: 8% TL; fin fold maximum width: 0.5 mm; yolk sac: 2.2 mm long. Myomeres: preanal, 27-30 (mode = 28); postanal, 16-22 (mode = 18); total, 44-50 (mode = 46). Morphometric data for protolarvae are given in Table 1.

Pigmentation: Head with minute stellate melanophores ('pepper-shot') lateral and dorsal areas (Fig. 1 A,B); postorbital patch; eyes: not pigmented except for light brown surface spots; yolk sac: dorsolateral small, round spots, concentration of ca. 10 spots on fin fold at yolk sac; lateral of body: melanophores mainly hypaxially, ventrolateral of intestine, ventral fin fold near urostyle; dorsal of body: few spots posterior of head; ventral of body: anterior of yolk sac unpigmented, otherwise spotted; myotomes light brown; anus with dark melanophores (Fig. 1 A).

2. Size 7.6-8.9 mm. Mouth open, not functional at 7.8 mm TL (Fig. 2 A); head not decurved over yolk sac; swim bladder visible but not fully functional; cleithrum formed; auditory vessicles visible at ca. 8.0 mm TL. At 8.5 mm TL, greatest fin fold width: 0.6 mm; yolk sac: 2.5 mm. Myomeres: preanal, 27-30 (mode = 29); postanal, 17-21 (mode = 19); total 44-49 (mode = 47).

Pigmentation: At ca. 8.0 mm, dorsal of body with a scatter of stellate melanophores, larger toward posterior (Fig. 2 B), dorsal aspect otherwise clear; venter with small light brown melanophores, intestine unpigmented (Fig. 2 C).

3. Size 9.0-11.0 mm. At 9.0 mm, (Fig. 3 A-C): yolk sac laterally bi-lobed (anterior: 0.4 mm, posterior: 2.2 mm, Fig. 3 A); cleithrum formed; eye: black; anus: short and broad; dorsal fin fold ca. 1.4 mm anterior to ventral fin fold. Swim-up at 9.7 mm. At 10.0 mm: (Fig. 4 A-C), feeding first occurs, lower jaw anterior to upper, pectoral fin: 1.0 mm, dorsal precedes by 0.8 mm ventral fin fold. At 11.0 mm (Fig. 5 A-C), yolk sac almost absorbed; dorsal, ventral fin folds greatly reduced; head: large, well-developed; eye with choroid fissure; anal fin anlages developing. Standard length: 98% TL; orbit: 9% TL; pectoral fin length: 1.1 mm. Myomeres: preanal, 26-30 (mode = 29); postanal, 17-22 (mode = 18); total, 45-49 (mode = 47).

Pigmentation: At 9.0 mm (Fig. 3): head with pepper-shot on dorsum; gill arches, suborbitals, upper ridge of jaws light brown; postorbital patch and subdermal band from head to yolk sac; a few large stellate melanophores at base of pectoral fin. At 10 mm: lateral of body with epaxial band on myotomes; caudal peduncle and ventral of caudal fin are light-brown; musculature generally unpigmented; dorsal of gut, intestine with large stellate melanophores; snout unpigmented, body with irregular series of stellate melanophores from head to anus, small fused spots thence to caudal area. Ventral of head mostly unpigmented, gular to gut outlined with a series of small dark spots; gill arches outlined with melanophores. At 11.0 mm: increased intensity of hypaxial pigmentation, mostly unpigmented epaxially (Fig. 5) several large stellates at base of pectoral fin.

Esox lucius (northern pike)

Ripe ovarian eggs ranged from 1.6 to 2.1 mm (mean = 1.9 mm); fertilized preserved eggs, range: 1.7-2.5 mm; (mean = 2.1 mm), N = 350.

1. Hatch to 8.9 mm. Newly hatched larvae ranged from 6.7 to 8.1 mm (mean = 7.7 mm); body: elongate, with large, slightly egg-shaped, yolk sac, over which head decurved (Fig. 6 A-C); urostyle extended to end of caudal fin fold; eye: large, with choroid fissure; paired adhesive glands anterior to and between orbits (Fig. 6 C); mouth: inferior, incomplete; oil globules: mostly lateroventral and posteroventral areas in dark yellow yolk. At hatch, small globules generally concentrated near surface in indistinguishable masses (Fig. 6 B,C), becoming distinguishable as minute (ca. 0.06 mm) spheres grouped in lots of 10-14 at 8 mm TL (Fig. 7 A). Pectoral buds at hatch; anus: abruptly decurved, long, thin, extended to margin of fin fold. At ca. 7.0 mm, fin fold maximum width: 0.7 mm; yolk sac: 2.9 mm. At ca. 8.0 mm (Fig. 7 A-C), standard length: 99% TL; orbit: 8% TL; pectoral fin buds: 0.3 mm; dorsal fin fold 0.9 mm anterior to ventral fin fold; auditory vessicles barely visible; ventral fin fold attached near centre of posterior margin of yolk sac. Fin fold maximum width at 8.9 mm TL: 0.6 mm; yolk sac: 3.0 mm. Myomeres: preanal, 40-46 (mode = 40); postanal, 23-27 (mode = 23), total, 66-72 (mode = 67). Table 2 lists morphometric data for protolarvae.

Pigmentation: Head: at hatch, large scattered stellate melanophores of light intensity (Fig. 6 B); postorbital patch (Fig. 7 A). By 8.9 mm, individual stellate and dendritic melanophores cover head; eye: at hatch, light pink to light brown, later becoming darker with small dendritic blotches; body: dorsally mainly clear; small spots hypaxially (Fig. 7 A), anterolateral areas, anus, light brown; spots develop later all over body; ventrolateral pigment somewhat diffused (Fig. 7 C); yolk sac: small stellate melanophore spots near body, increasing in size ventrally; unpigmented patch anteroventral of yolk sac (Fig. 7 C).

2. Size 9.0-10.9 mm. Body dominated by oblong, 3.0 mm yolk sac; ventral fin fold attached at centre margin of yolk sac (Fig. 8 A). At 9.0 mm: fin fold greatest width: 1.5

mm; orbit 0.7 mm. At 10.0 mm TL, mouth agape but not functional; individual oil globules; pectoral fin: 0.8 mm. Myomeres: preanal 39-41 (mode = 40); postanal 20-26 (mode = 22); total 60-66 (mode = 62).

Pigmentation: Body-length stripe of melanophores developing at 9.0 mm TL, becoming obvious at 10.0 mm (Fig. 8 A); anus dark brown; eye: brown. Late in size class, body dominated by hypaxial stripe of melanophores; head spotted with small dark melanophores, except postorbital unpigmented patch; spots on yolk sac near body become fused near anus; ventral stripe from anus to caudal region.

3. Size 11.0-14.5 mm. At 11.0 mm: head dominated by large (37% head length) orbit (Fig. 9 A); fin fold greatest width: 0.7 mm. At 12 mm: bladder visible; cleithrum formed; dorsal fin fold precedes by 1.0 mm ventral; pectoral fin: 1.2 mm. At 13 mm: elongation of snout, lower jaw anterior to upper; orbit extended into dorsal profile. At 13.2 mm, swimming started, and at 13.5 mm, pelvic buds formed. Near the end of the size class, larvae characterized by large head and eyes, teeth (dentary and premaxillary) conspicuous, short snout and a trace of yolk in ventral of yolk sac. At 14.5 mm: dorsal fin fold origin at tenth myomere; orbit: 1.2 mm (8% TL); snout length: 0.7 mm; pelvic buds: 0.5 mm. Myomeres: preanal, 19-24 (mode = 38); postanal, 37-41 (mode = 21); total, 57-63 (mode = 59).

Pigmentation: Body: dorsal ridge with irregular line of large stellates extending to posterior of yolk sac (Fig. 9 A,B); epaxial region lightly spotted; hypaxial body-length stripe with large sub-surface stellate melanophores; yolk sac with minute, black spots laterally and dorsally; base of pectoral fin with large stellate melanophores; head: patch of melanophores on snout, both jaws with spots; suborbital line and postorbital patch joined at gill arches, which are clearly outlined with subsurface brown pigment; eyes: black (at 12.0 mm TL).

Esox masquinongy (muskellunge)

Ripe ovarian eggs (N = 250) ranged from 2.2 to 3.2 mm (mean = 2.7 mm); fertilized preserved eggs (N = 240), range 2.7-3.2 mm (mean = 2.9).

1. Hatch to 8.9 mm. Newly hatched larvae ranged from 7.8 to 8.9 mm (mean = 8.5 mm); body: elongate, dominated by oval yolk sac, with enclosed amber yolk; oil globules (ca. 0.1 mm) usually individual, occasionally in groups, situated near surface, mainly ventrally; head: decurved over anterior margin of yolk sac (Fig. 10 A); occipital lobe large; auditory vesicles visible; mouth inferior, incomplete, closed; adhesive glands immediately anterior of orbits (Fig. 10 C); ventral fin fold attached near ventral margin of yolk sac; dorsal fin fold origin at nape; anus: abruptly decurved, long, thin, extends to margin of ventral fin fold; pectoral fin buds formed. At ca. 8.0 mm: standard length 99% TL; fin fold maximum width: 0.6 mm; orbit: 36% head length (6% TL); pectoral fin: 0.4 mm; yolk sac: 3.3 mm. Myomeres: preanal, 41-43 (mode = 43); postanal, 23-25 (mode = 25); total, 66-68 (mode = 68). Table 3 lists morphometric data for protolarvae.

Pigmentation: Body-length hypaxial band of melanophores; a few individual stellate melanophores on dorsal ridge; intestine pigmented ventrally; patch of melanophores ventral area of caudal fin fold (Fig. 10 A); head: basically unpigmented dorsally, suborbital patch of melanophores; gill arches outlined in dark brown; eyes: light brown subsurface, large dendritic melanophores at posterior margin; yolk sac: dorsolateral areas with brown pigment.

2. Size 9.0-10.9 mm. Body: depth increased anteriorly (Fig. 11 A); head: occiputal lobe reduced; mouth formed at 9.0 mm TL; eye: elliptical; yolk sac: 3.6 mm; oil globules golden, usually singular (0.08-0.16 mm); fin fold greatest width: 1.0 mm. At 10.0 mm, yolk volume much reduced; fin fold greatest width: 0.8 mm; oil globules subsurface (Fig. 11 B, C). At 10.8 mm: head slightly decurved, but free from yolk sac; mouth open; pectoral fin and orbit similar in size (0.5 mm), located ventrolaterally; snout slightly pointed. Myomeres: preanal, 40-44 (mode = 42); postanal, 25-26 (mode = 25); total, 65-68 (mode = 67).

Pigmentation: On head, suborbital and postorbital patches, gill arches clearly outlined by melanophores (Fig. 10 A). A crescent-shaped patch on anterolateral margin of yolk sac connects with body-length hypaxial stripe, which joins epaxial area of body posterior of anus, the posterior of which is also pigmented. A few stellates along dorsal ridge and at base of pectoral fins. Yolk sac: posterior third covered with diagonal patch of stellate melanophores (Fig. 11 A); pigmentation lacking anteroventrally.

3. Size 11.0-14.5 mm. At 11.0 mm, (Fig. 12 A-C), body still dominated by yellow yolk in oblong sac, containing ca. 40 large (0.1 - 0.2 mm) globules, located anteroventally; yolk occupies ca. 85% yolk sac; head free from yolk sac, but joined by ventrolateral pair of membranes (scarcely visible); orbit: 33% head length; dorsal fin fold origin at seventh or eighth myomere; ventral fin fold joins yolk sac at ventral margin; greatest width of fin fold: 0.8 mm; adhesive glands still evident (Fig. 12 C). At 12.6 mm cleithrum formed; pectoral fin length: 1.1 mm, orbit: 0.8 mm, and at ca. 13.5-14.0 mm, lengths are 1.3 and 1.4 mm, respectively. At 14.0 mm, caudal fin fold in form of an arrowhead, hypurals forming; lower jaw preceeds upper jaw (Fig. 13). At 14.5 mm: standard length 99% TL; orbit: 7% TL; pelvic

buds formed; snout length: 0.9 mm; teeth not conspicuous. Myomeres: preanal, 40-43 (mode = 41); postanal, 20-25 (mode = 23); total, 61-69 (mode = 64).

Pigmentation: Head and body-long, hypaxial stripe of melanophores; dorsal and ventral of head, snout mostly unpigmented; eyes: black (at ca. 11.0 mm); maxillae with band of dark melanophores; ventral fin fold between yolk sac and anus, unpigmented; obvious band of melanophores at site of first developing caudal fin rays; lateral posterior third of body pigmented (Fig. 13).

SUMMARY OF CHARACTERISTICS FOR SEPARATION

Cursory examination of the pigmentation, oil globule size and distribution, and preanal myomere count will assure separation of grass pickerel from northern pike and muskellunge. However, the relative similarity of northern pike and muskellunge in myomere count and preanal length at most comparative sizes necessitates closer scrutiny of these species. If differences are not evident in head, eye, and yolk sac pigmentation, and the size and form of oil globules, separation should result from several additional comparisons. In northern pike, head length and snout to ventral fin fold length, relative to total length, are greater, and the yolk sac smaller, than in muskellunge (Table 2, Table 3, Fig. 13 and Fig. 14). A number of criteria for distinguishing between protolarvae of grass pickerel, northern pike, and muskellunge are given in Table 4.

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Table 1. Morphometry of Esox americanus vermiculatus protolarvae, expressed as a percentage of total length. N = number; lengths in millimeters.

Size Class (TL)	N	TL	Percentage of Total Length					
			Head	Snout to Ventral Finfold	Orbit to Anus	Yolk Sac to Anus	Preanal	Yolk Sac
5.0- 5.9	3	5.8	19	43	61	25	69	37
6.0- 6.9	15	6.2	18	42	59	24	68	35
7.0- 7.9	16	7.7	18	39	55	23	65	30
8.0- 8.9	23	8.5	19	39	53	22	64	29
9.0- 9.9	29	9.4	22	39	58	23	65	26
10.0-10.9	79	10.4	26	41	52	21	65	21
11.0-11.9	2	11.0	26	40	51	25	66	--

Table 2: Morphometry of Esox lucius protolarvae, expressed as a percentage of total length. N = number, lengths in millimeters.

Size Class (TL)	N	TL	Percentage of Total Length					
			Head	Snout to Ventral Finfold	Orbit to Anus	Yolk Sac to Anus	Preanal	Yolk Sac
6.0- 6.9	1	6.7	18	52	68	25	76	43
7.0- 7.9	7	7.7	21	46	67	29	75	36
8.0- 8.9	13	8.4	19	41	63	27	73	35
9.0- 9.9	5	9.4	20	45	59	26	70	34
10.0-10.9	17	10.4	18	43	59	25	69	32
11.0-11.9	19	11.3	20	42	57	24	67	30
12.0-12.9	15	12.6	23	41	53	22	67	25
13.0-13.9	28	13.5	25	45	54	22	66	21
14.0-14.9	41	14.4	25	45	52	--	66	--

Table 3. Morphometry of Esox masquinongy protolarvae, expressed as a percentage of total length. N = number; lengths in millimeters.

Size Class (TL)	N	TL	Percentage of Total Length					
			Head	Snout to Ventral Finfold	Orbit to Anus	Yolk Sac to Anus	Preanal	Yolk Sac
7.7- 7.9	1	7.8	15	41	56	26	73	42
8.0- 8.9	16	8.6	16	41	60	26	70	38
9.0- 9.9	20	9.4	16	42	59	24	68	40
10.0-10.9	19	10.6	16	40	58	23	68	37
11.0-11.9	16	11.5	17	39	58	22	68	35
12.0-12.9	20	12.5	18	40	57	22	68	30
13.0-13.9	31	13.4	20	41	55	21	67	29
14.0-14.9	16	14.4	23	41	55	--	68	22
15.0-15.9	10	15.4	24	42	54	--	68	8

Table 4. Distinguishing features (generalized) of the protolarvae of three esocids. Lengths in millimeters.

Feature	E. americanus v.	E. lucius	E. masquinongy
Mean size at hatch (TL)	6.1	7.7	8.5
Total myomeres	45-49	57-72	61-69
Yolk sac at hatch			
length (% TL)	32	35	39
pigmentation	dark pepper-shot	spotted, blotched	scant, diffused
oil globules	minute, clustered	small, massed	large, single
Yolk sac absorbed (TL)	11.0	14.0	14.5
Head length (% TL)			
hatch	18	20	16
11.0 mm	26	20	17
Preanal length (% TL)			
hatch	68	76	70
11.0 mm	66	67	68
Onset of events (TL)			
blackening of eyes	9.0	10.5	11.0
budding of pelvic fins	11.5	13.5	14.5
snout elongation	10.0	13.0	14.0
orbit in dorsal profile	11.0	13.0	late phase (ca. 16)
swim bladder visible	10.0	12.0	14.0

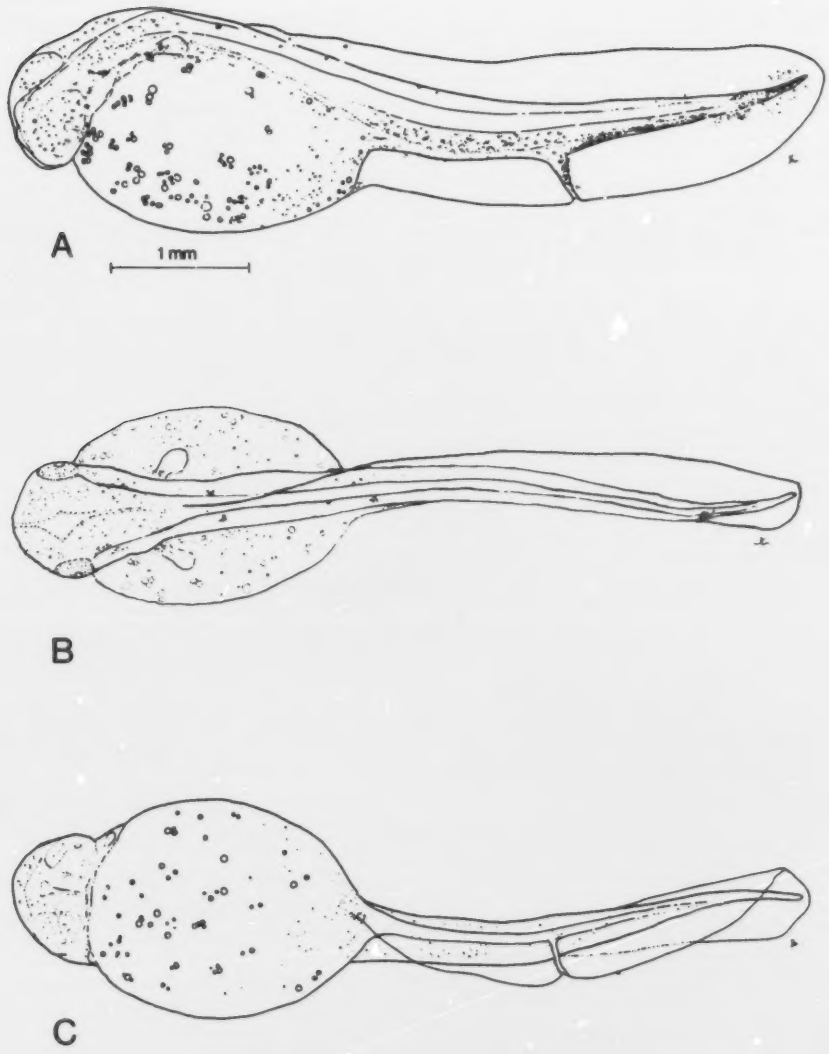

Figure 1 Esox americanus vermiculatus protolarvae, 6.0 mm (A - lateral, B - dorsal, C - ventral view).

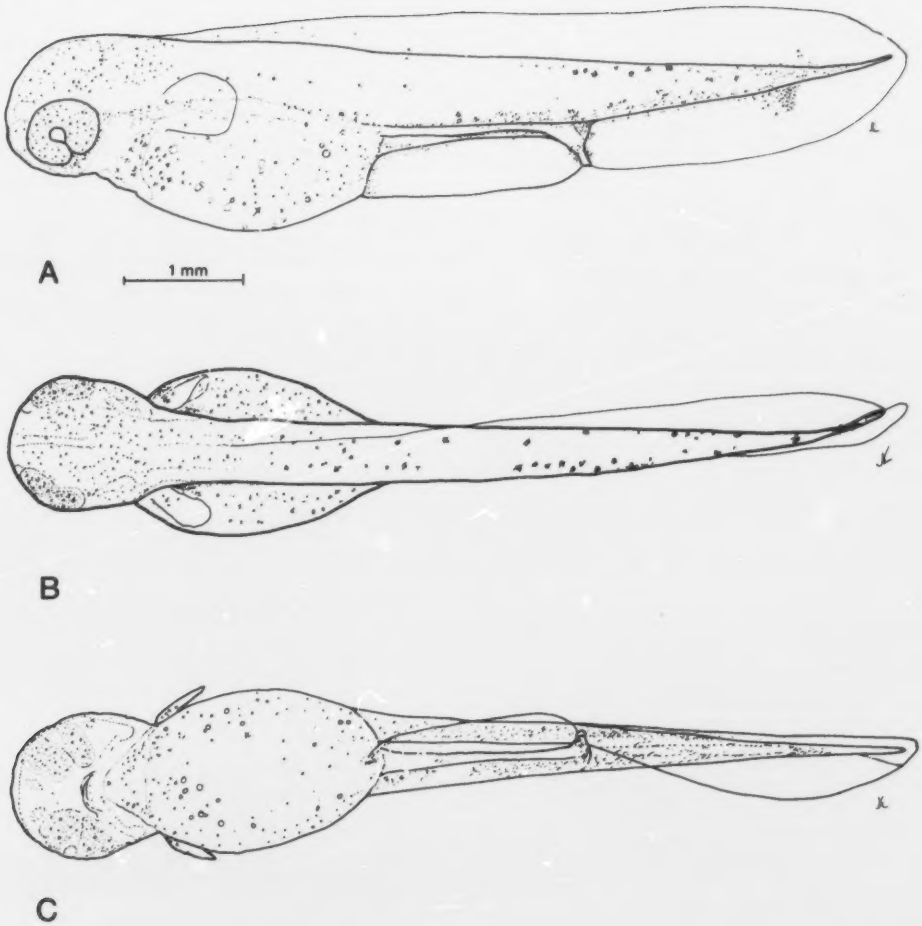

Figure 2 Esox americanus vermiculatus protolarvae, 7.8 mm (A - lateral, B - dorsal, C - ventral view).

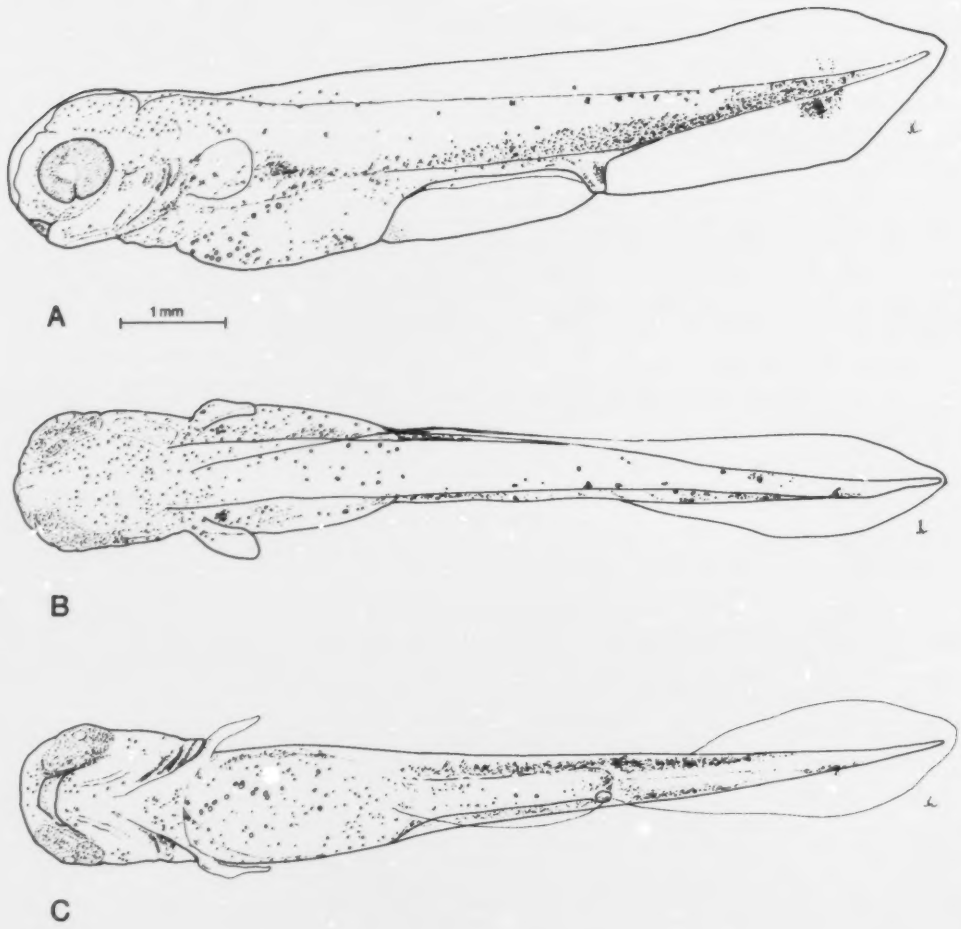

Figure 3 Esox americanus vermiculatus protolarvae, 9.0 mm (A - lateral, B - dorsal, C - ventral view).

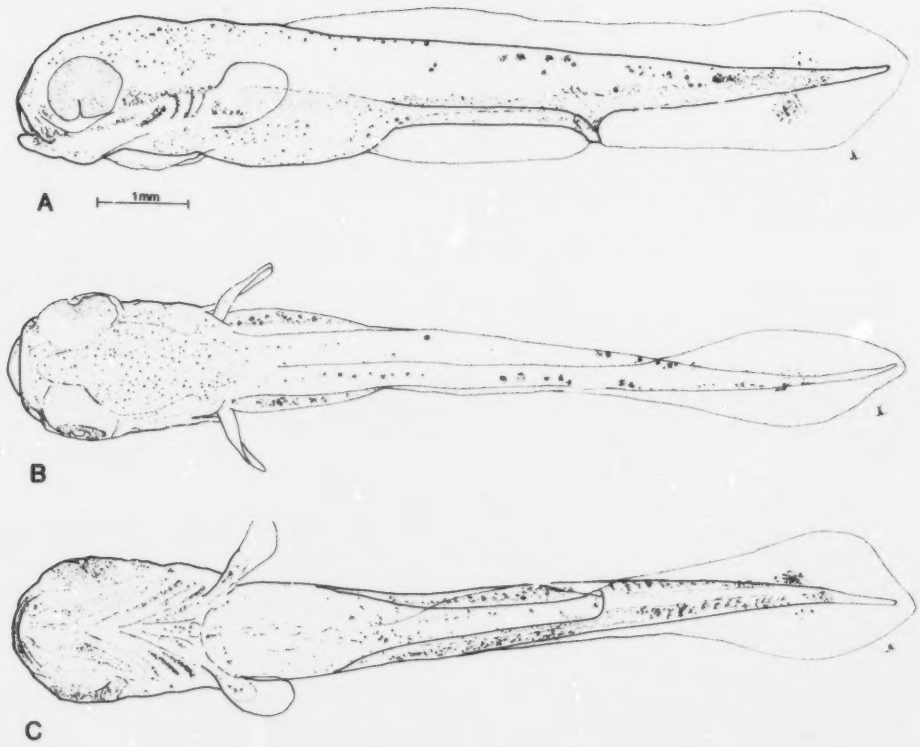

Figure 4 Esox americanus vermiculatus protolarvae, 10.0 mm (A - lateral, B - dorsal, C - ventral view).

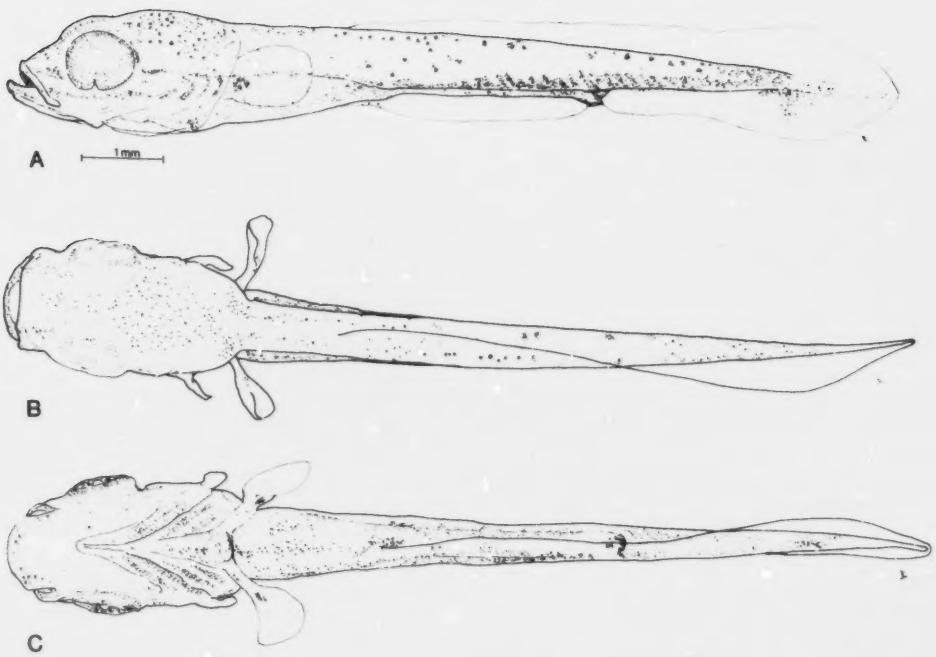

Figure 5 Esox americanus vermiculatus protolarvae, 11.0 mm (A - lateral, B - dorsal, C - ventral view).

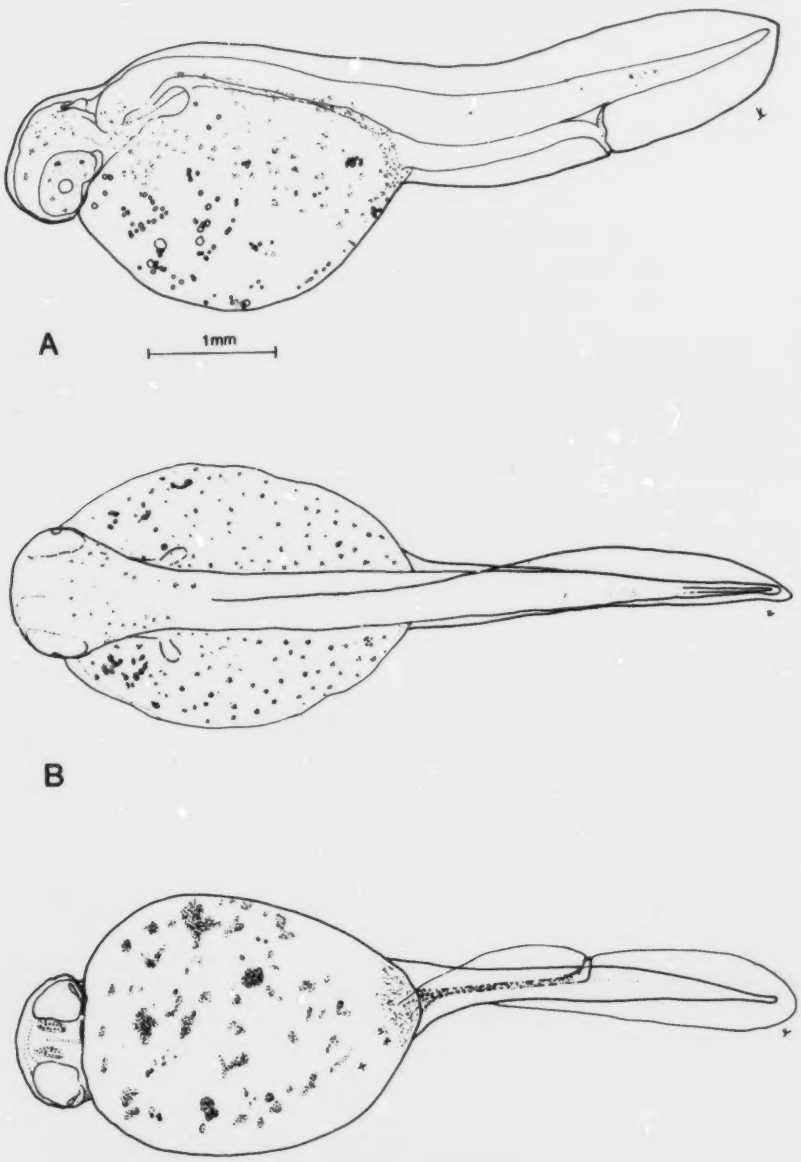

Figure 6 Esox lucius protolarvae, 6.7 mm (A - lateral, B - dorsal, C - ventral view).

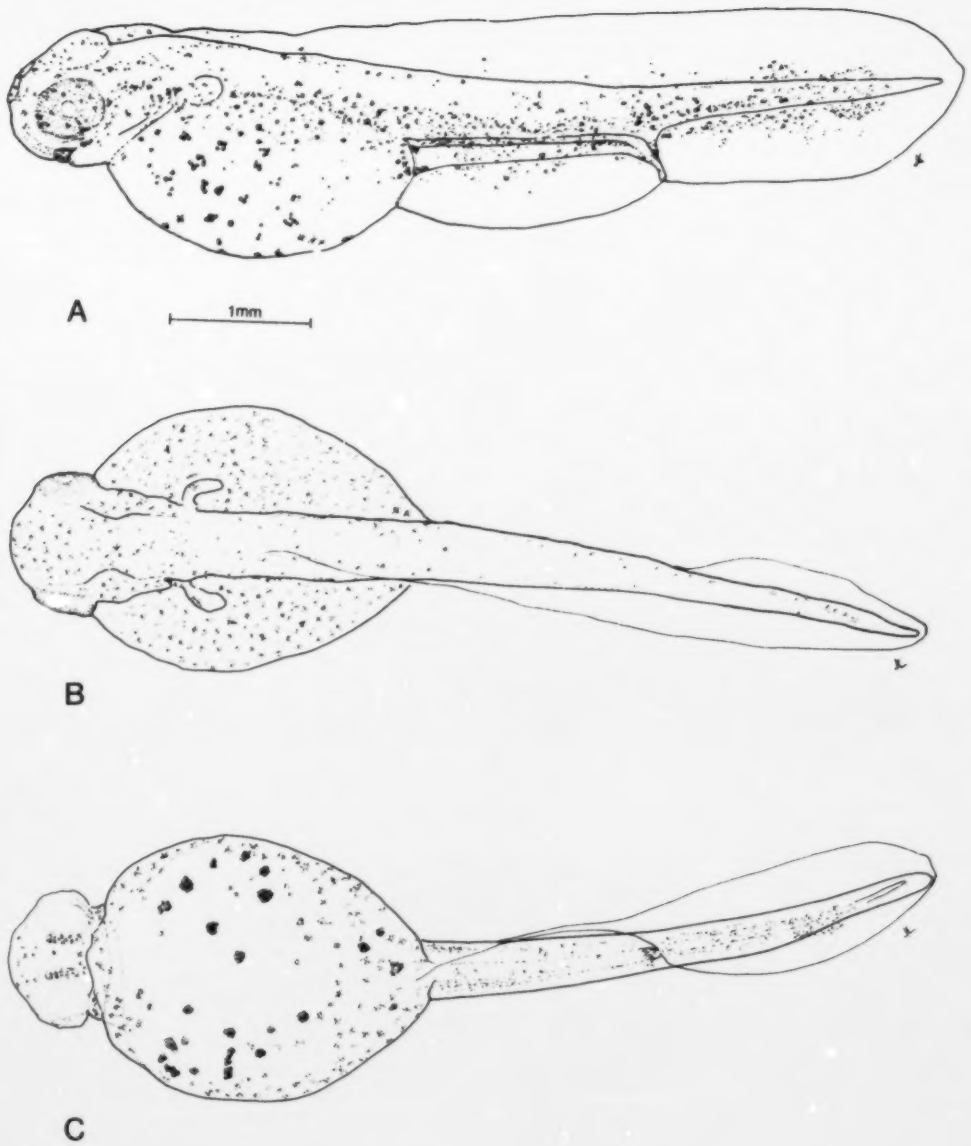

Figure 7 Esox lucius protolarvae, 8.0 mm (A - lateral, B - dorsal, C - ventral view).

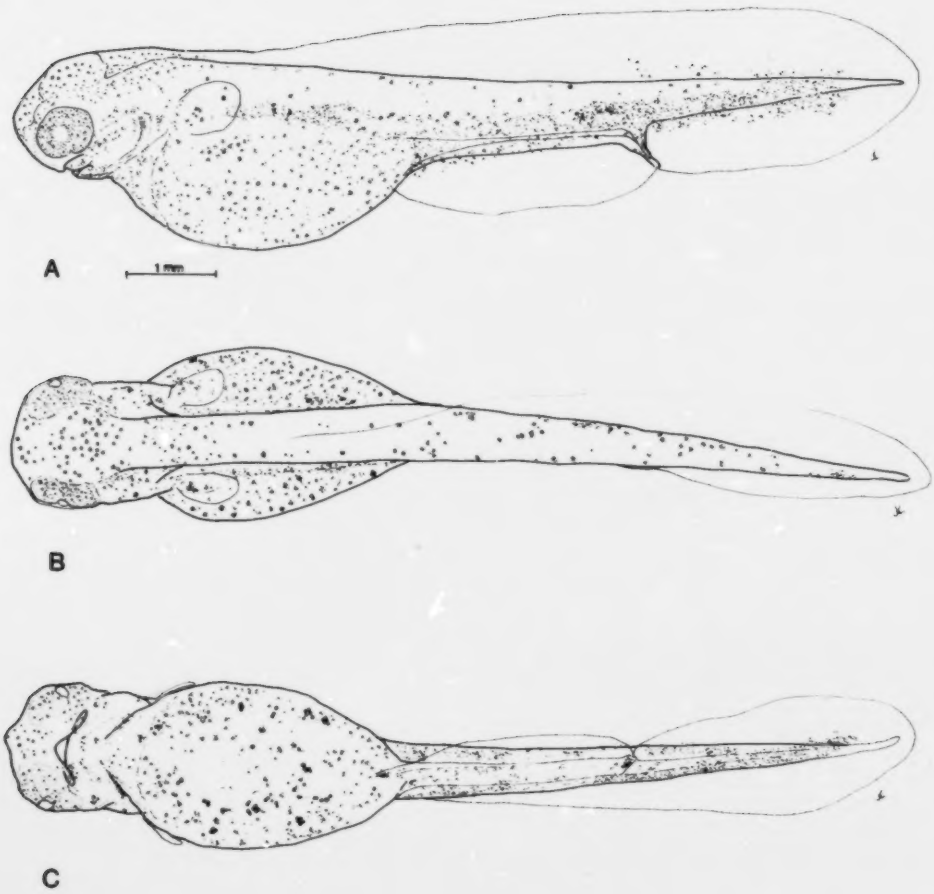

Figure 8 Esox lucius protolarvae, 10.0 mm (A - lateral, B - dorsal, C - ventral view).

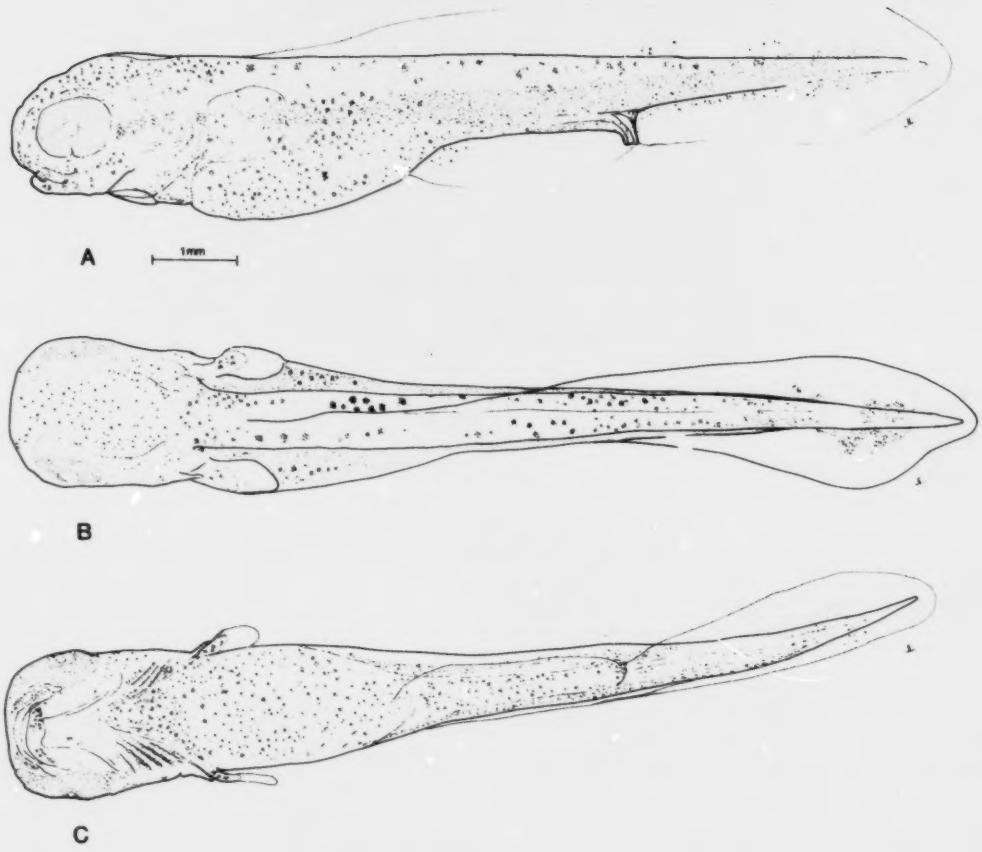

Figure 9 Esox lucius protolarvae, 11.0 mm (A - lateral, B - dorsal, C - ventral view).

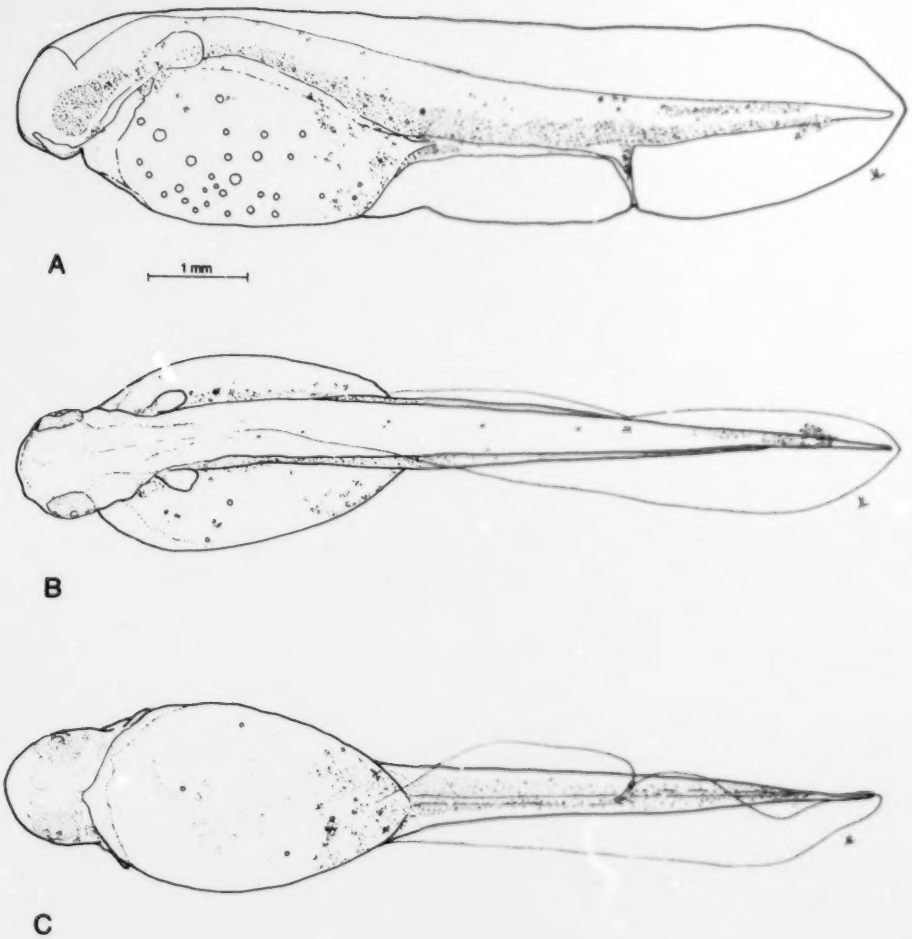

Figure 10 Esox masquinongy protolarvae, 9.0 mm (A - lateral, B - dorsal, C - ventral view).

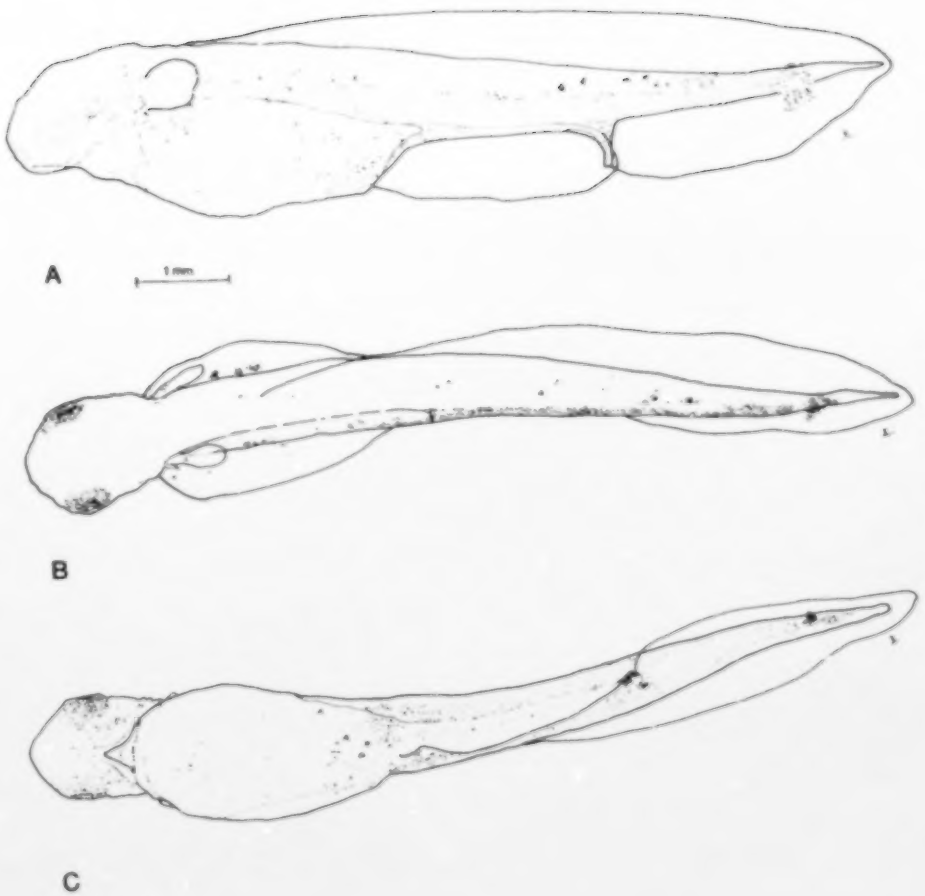

Figure 11 Esox masquinongy protolarvae, 10.0 mm (A - lateral, B - dorsal, C - ventral view).

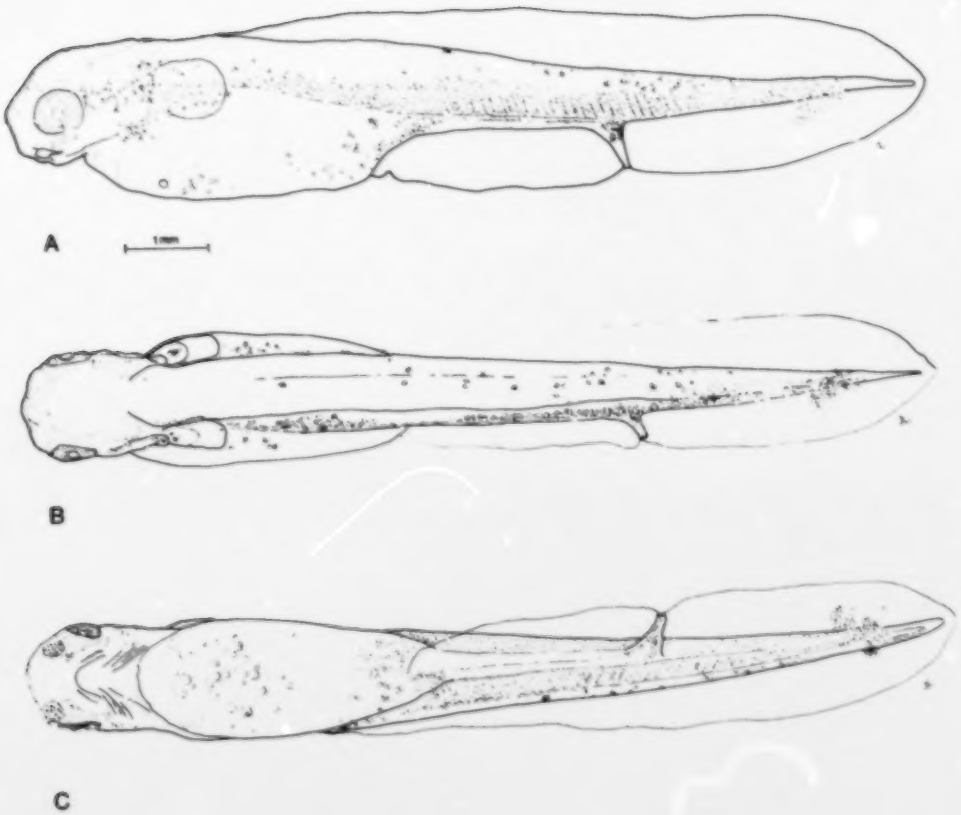

Figure 12 Esox masquinongy protolarvae, 11.0 mm (A - lateral, B - dorsal, C - ventral view).

Figure 13 Esox masquinongy protolarva, 14.1 mm, lateral view.

Figure 14 Esox lucius protolarva, 14.0 mm, lateral view.

Kendall, A.W., Jr. and J.H. Marliave (editors). 1985. Descriptions of early life history stages of selected fishes: from the 3rd International Symposium on the Early Life History of Fishes and 8th Annual Larval Fish Conference, May 1984, University of British Columbia, Vancouver, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 1399. 82 p.

Description of larval pirate perch, Aphredoderus sayanus (Gilliams) from the Savannah River.

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INTRODUCTION

The pirate perch, Aphredoderus sayanus is the only living member of the family Aphredoderidae, one of three families in the North American order Percopsiformes. It occurs in the southern portions of the Great Lakes drainage, the Mississippi Valley and the lowlands of the Gulf and Atlantic slopes from Texas through New York (Eddy and Underhill 1974; Lee et al. 1980). Western and eastern subspecies, A. s. gibbosus and A. s. sayanus, respectively, are recognized by some authors and questioned by others (Bailey et al. 1954; Smith 1979; and Lee et al. 1980). The pirate perch is nocturnal in behavior and typically inhabits marshes, swamps, estuaries, bottomland lakes, overflow ponds and quiet springs, pools, backwaters, and oxbows of low-gradient streams with an abundance of vegetation, organic debris, or other cover (Abbott 1861; Jordan and Evermann 1896; Becker 1923; and Becker 1983).

One of the more unusual features of adult pirate perch is the jugular position of the vent. Mansueti (1963) documented the migration of the vent from a more typical abdominal position (just anterior to the anal fin) in metalarvae to its adult position beneath the heart in specimens over 60 mm total length (TL).

Aside from Mansueti's (1963) well illustrated description of metalarvae and juveniles, the only published information on pirate perch larvae originated with Martin and Hubbs (1973), Hogue et al. (1976) and Hardy (1978), and was summarized by Hardy (1978), Wang and Kernehan (1979), and Auer (1982). Martin and Hubbs (1973) described aspects of the development from fertilized egg through a few days after hatching, but provided neither illustrations nor size data for the larvae; they did, however, note that fertilized eggs were about 1.0 mm in diameter with single oil globules under 0.4 mm in diameter. Hardy (1978) included supplemental notes by Martin and drawings of a fertilized egg and three recently hatched protolarvae based on photographs. Again, the lengths of the larvae illustrated were not recorded and, unfortunately, the specimens are not available (F.D. Martin personal communication). Hogue et al. (1976) provided a photograph of an 8 mm TL specimen and some descriptive notes based on three Tennessee River larvae. Some of the information summarized by Auer (1982) appears to be mistakenly attributed to specimens about 4 mm TL.

The following account is intended to partially fill the gap in our knowledge of pirate perch larvae, especially mesolarvae, and provide a basis for distinguishing them from the larvae of other species. Unfortunately, information on the protolarvae and recently transformed mesolarvae remains incomplete.

MATERIALS AND METHODS

Pirate perch larvae were collected during an ichthyoplankton survey in the Savannah River (South Carolina and Georgia) between River Mile 157.3 near the Department of Energy's Savannah River Plant and River Mile 44.8 near Ebenezer Creek.

Ichthyoplankton samples were collected with paired 0.5 m, 505 µ, conical nets, preserved in buffered 5 % formalin and stained with Eosin B and Biebrich scarlet to facilitate sorting. After sorting, specimens were stored in 70 % ethanol. Shrinkage due to alcohol preservation must be considered when comparing our results with living, freshly killed or formalin-preserved specimens. A series of 33 larval specimens from 5.8 mm TL to 14.7 mm TL were collected during March, April and May 1983.

Selected measurements, fin ray counts, myomere counts, and developmental terminology followed Snyder (1981). Measurements used in this account are defined in Table 1. Specimens were examined and analyzed under a stereomicroscope fitted with polarizing filters (useful for myomere and fin ray counts) and a calibrated ocular micrometer. Morphometrics were expressed as percent standard length to avoid erroneous data based on damaged caudal rays and the allometric influence of the caudal fin on total length. All standard length measures were made to the posterior margin of the hypural plate. Some developmental data for stages earlier than those examined were extracted from previous published accounts and a personal

Kendall, A.W., Jr. and J.B. Marliave (editors). 1985. Descriptions of early life history stages of selected fishes: from the 3rd International Symposium on the Early Life History of Fishes and 8th Annual Larval Fish Conference, May 1984, University of British Columbia, Vancouver, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 1359: 82 p.

Table 1. Selected morphometric data expressed as percent standard length (%SL) for mesolarvae and metalarvae of Aphredoderus sayanus from the Savannah River.

Parameter	Mesolarvae x ± SD	Range	N	Metalarvae x ± SD	Range	N
Size, mm						
Total Length	6.6 ± 0.6	5.8 - 7.7	14	10.8 ± 2.0	8.2 - 14.7	19
Standard Length	5.6 ± 0.4	5.1 - 6.4	14	8.7 ± 1.5	6.7 - 11.8	19

Parameter	Mesolarvae x ± SD	Range	N	Metalarvae x ± SD	Range	N
Length, % SL						
Anterior margin of snout (AS) to:						
Anterior margin of eye (AE)	6 ± 1	5 - 8	14	9 ± 1	7 - 11	19
Posterior margin of the eye (PE)	14 ± 2	12 - 17	14	18 ± 1	17 - 20	19
Origin of pectoral fin (OP1)	28 ± 2	25 - 33	14	33 ± 2	30 - 36	19
Posterior margin of operculum (PO)	30 ± 3	26 - 34	14	37 ± 2	33 - 39	19
Origin at pelvic fin (OP2)	-	-	-	42 ± 2	37 - 44	19
Origin of preanal finfold (OPAF)	44 ± 5	31 - 51	13	50 ± 6	31 - 57	17
Origin of dorsal finfold (ODF)	35 ± 4	28 - 44	14	42 ± 2	32 - 45	18
Origin of dorsal fin (OD)	45 ± 2	42 - 47	13	47 ± 1	44 - 49	19
Insertion at dorsal fin (ID)	64 ± 4	61 - 69	4	69 ± 2	65 - 72	19
Posterior margin of vent (PV)	55 ± 2	51 - 59	14	60 ± 2	57 - 62	19
Origin of anal fin (OA)	62 ± 1	60 - 64	12	64 ± 2	62 - 67	19
Insertion of anal fin (IA)	72 ± 2	71 - 75	4	76 ± 3	71 - 81	19
Posterior margin of caudal fin (PC)	117 ± 4	109 - 122	14	124 ± 2	119 - 127	19
Pectoral fin (PI)	18 ± 3	14 - 23	14	22 ± 2	17 - 24	19
Pelvic fin (P2)	-	-	-	6 ± 4	1 - 14	19
Dorsal fin (D)	21 ± 2	20 - 23	4	29 ± 3	23 - 34	18
Anal fin (A)	12 ± 1	12 - 13	4	18 ± 4	11 - 24	18
Depths, % SL at						
Posterior margin of eye (BPE)	22 ± 2	18 - 25	14	27 ± 1	25 - 29	19
Origin of pectoral fin (OP1)	23 ± 2	20 - 28	14	29 ± 2	25 - 31	19
Origin of dorsal fin (OD)	19 ± 3	15 - 23	14	26 ± 2	20 - 29	19
Posterior margin of vent (BPV)	10 ± 2	7 - 15	14	17 ± 4	11 - 22	19
Origin of anal fin (OA)	9 ± 1	7 - 11	14	16 ± 3	11 - 20	19
Anterior margin of posterior myomere (AMPM)	6 ± 1	5 - 8	14	10 ± 1	8 - 13	19
Widths, % SL at						
Posterior margin of eye (BPE)[a]	20 ± 2	17 - 24	14	23 ± 2	19 - 28	19
Origin of pectoral fin (OP1)[a]	13 ± 1	11 - 16	14	16 ± 1	14 - 18	19
Origin of pectoral fin (OP1)[b]	20 ± 3	13 - 23	14	23 ± 2	20 - 29	19
Origin of dorsal fin (OD)	9 ± 3	6 - 12	14	14 ± 1	11 - 16	19
Posterior margin of vent (BPV)	6 ± 1	5 - 7	14	9 ± 2	6 - 11	19
Origin of anal fin (OA)	6 ± 1	5 - 7	14	8 ± 2	6 - 9	19
Anterior margin of posterior myomere (AMPM)	4 ± 1	3 - 5	14	4 ± 1	3 - 5	19

[a] Exclusive of opercula.

[b] Inclusive of opercula.

communication (see Table 2). Illustrations were initially traced from photographs to assure accurate proportions and structure location. Details and pigmentation were completed while examining the photographed specimen and additional, similar sized larvae.

Table 2. Size (mm standard length/mm total length) at the apparent onset of selected developmental events for Aphredoderus sayanus. Referenced structures are observable under low power magnification. Rare or questionable extremes are enclosed in parentheses. Question marks indicate extracted or otherwise unverified data.

Hatching	? 2-3/(2)3[a]
Eyes pigmented	? (2)3/(2)3[a]
P1 bud formation	? 3/3(4)[a,b]
P2 bud formation	(6)7/8
Yolk completely absorbed	? (3)4/4(5)[b]
Finfold completely absorbed	12/15-16
Gut coil or loop formation, as evidenced by at least a 90° bend	? ≤4(5)/≤5
Segmentation evident in the principal rays of all fins	9-10/12-13

Fin rays	First observed	Adult complement
Principal C	? 3-4/4[a,b]	? (4)5/5-6[b]
Secondary C	7/(8)9	9/(11)12
Principal D	(5)6/(6)7	6-7/(7)8
Principal A	6/7	6-7/(7)8
P1	5/6	6-7/(7)8
P2	8/10	11-12/14

Scales	
initial appearance	10/ 12-13
full coverage	? ≥20/≥24[c]

[a] Based on drawings of recently hatched specimens illustrated in Hardy (1978); sizes were approximated by extrapolation from size of yolk and oil in an illustrated egg assumed to be about 1.0 mm in diameter.

[b] Based, at least in part, on state of development reported for a 4.3 mm specimen which possesses little yolk, pectoral fin buds and a few caudal rays (D. Lowery, personal communication).

[c] Based on visual examination under the microscope of specimens not stained for this purpose.

RESULTS

Morphometrics, developmental state relative to size and myomere counts are summarized in Tables 1, 2 and 3, respectively. Body form and pigmentation are illustrated in Figures 1, 2 and 3. Pirate perch larvae are distinguished by a relatively short preanal length, the triangular shape of the gut region, anterior air bladder position, relative position of dorsal and anal fin, 14-17 postanal myomeres (Table 3), 18 principal caudal rays and very distinct pigmentation. Large stellate melanophores are concentrated on top of the head, laterally in the gut region and a few mid-laterally on the body. Suborbital bar pigment exists in all of our larval specimens.

Our smallest mesolarvae (5.8 mm TL) has a full complement of principal caudal rays (although some are poorly defined), pectoral fins without rays, an air bladder, dorsal and anal fin folds with a few dorsal fin pterygiophores forming, a fairly large head and large stellate melanophores, especially over the head and gut region (Figure 1). A distinct crescent of melanophores at the base of the caudal fin is present in some later mesolarvae. Mesolarvae have well developed median fins by 8 mm TL (Table 2). Transformation to metalarval phase occurs at about 8 mm TL with the acquisition of the adult complement of principal rays in the median fins and the appearance of pelvic fin buds.

As pirate perch larvae increase in size, their body proportions change considerably relative to standard length (Table 1). Head length (OP1) increased from a mesolarva mean of 28 percent SL to a metalarva mean of 33 percent SL (30 to 37% SL based on PO). Preanal length (PV) increased from 55 to 60 percent SL (Table 1). Body depth and body

width increased at all points measured, except width at AMPM (Table 1). Other changes, except for the morphogenesis of the fins, are less pronounced. There is an increase in small melanophores scattered over the body until the body attains a dusky coloration early in the juvenile period. The suborbital bar is very distinct on metalarvae (Figure 3). The pelvic fin buds are present by 8 mm TL and develop a full complement of fin rays by about 13.5 mm TL (Table 2). The anus commences its anterior migration around 9 mm TL (Hardy 1978); however, very little anal migration occurs during the metalarval phase. Most of the migration occurs during the juvenile period (Mansueti 1963). The preanal finfold persists to about 15 - 16 mm TL (Table 2). Specimens 15 mm TL are considered to be juveniles with the attainment of a full complement of fin rays, segmentation apparent in median fin rays and the absence of finfolds. Hardy (1978) describes a juvenile as having a minimum length of 14 mm TL.

Table 3. Frequency distribution of myomere counts for pirate perch mesolarvae (N=14) and metalarvae (N=19), from the Savannah River. See Snyder 1981 for count criteria.

	Myomere count	No. of larvae: Meta-larvae	Meso-larvae
Preanal (to posterior margin of vent)	12	4	5
	13	5	7
	14	11	2
	14	4	2
	15	12	5
Postanal	16	3	6
	17	0	1
	27	3	3
Total	28	5	4
	29	10	7

DISCUSSION

The later mesolarvae and metalarvae of pirate perch from the Savannah River are very similar to the larvae described by Hogue et al. (1976) and Mansueti (1963). However, pigmentation differences between Savannah River specimens and the 8 mm TL Tennessee River specimen illustrated by Hogue et al. (1976) are notable. In contrast to Savannah River specimens (Figure 3), the Tennessee River specimen exhibited melanophores distributed more evenly over the head and body. Also, in Hogue's specimens the range of preanal and postanal myomeres differ by one from our specimens. Our pirate perch have their adult complement of median fin rays by 12 mm TL. Hogue et al. (1976) reports this event to occur at 13 mm TL. The differences may reflect differences in preservation, collection from different environments or genetic differences between populations or subspecies.

Several genera of the Centrarchidae may be difficult to distinguish from pirate perch. Larvae of an Elassoma species taken in Savannah River ichthyoplankton collections were found to be very similar to pirate perch in appearance, developmental state relative to size and total myomeres. The most obvious difference between Aphredoderus and Elassoma is in pigment. The Elassoma larvae have small melanophores scattered rather uniformly over much of the head and body as well as a broad ovoid midventral band anterior to the vent with a very dense spot at the anterior apex of the band. However, since distribution of melanin in melanophores depends in many cases on the larva's environment, the appearance could vary with habitat. Less obvious and definitive criteria noted in preliminary comparisons include slightly higher postanal myomere counts of 17 or 18 and earlier pelvic bud formation at about 6 mm SL or 7 mm TL for Elassoma. Once the adult complement of principal caudal rays are present, in the mesolarvae phase, counts of 18 for pirate perch and 16 or fewer for Elassoma species (Conner 1979) serve as good criteria for diagnosis. Metalarvae are readily segregated on the basis of fin meristics and position (e.g., dorsal fin insertion well anterior to anal fin insertion in pirate perch, but over the anal fin insertion in Elassoma).

The higher postanal myomere count (19 - 23 postanal myomeres), air bladder development and position of dorsal and anal fin readily separates Centrarchus and Pomoxis larvae from pirate perch larvae. Unlike pirate perch, the Centrarchus and Pomoxis larvae develop an air bladder which extends posteriorly to or beyond the anus (Conner 1979).

The protolarvae and mesolarvae of Enneacanthus and possibly Acantharchus might also prove to be quite similar to pirate perch. Unfortunately, we are not aware of descriptions of Enneacanthus mesolarvae or any larval phase of Acantharchus, and, as mentioned earlier, our knowledge of pirate perch protolarvae is inadequate.

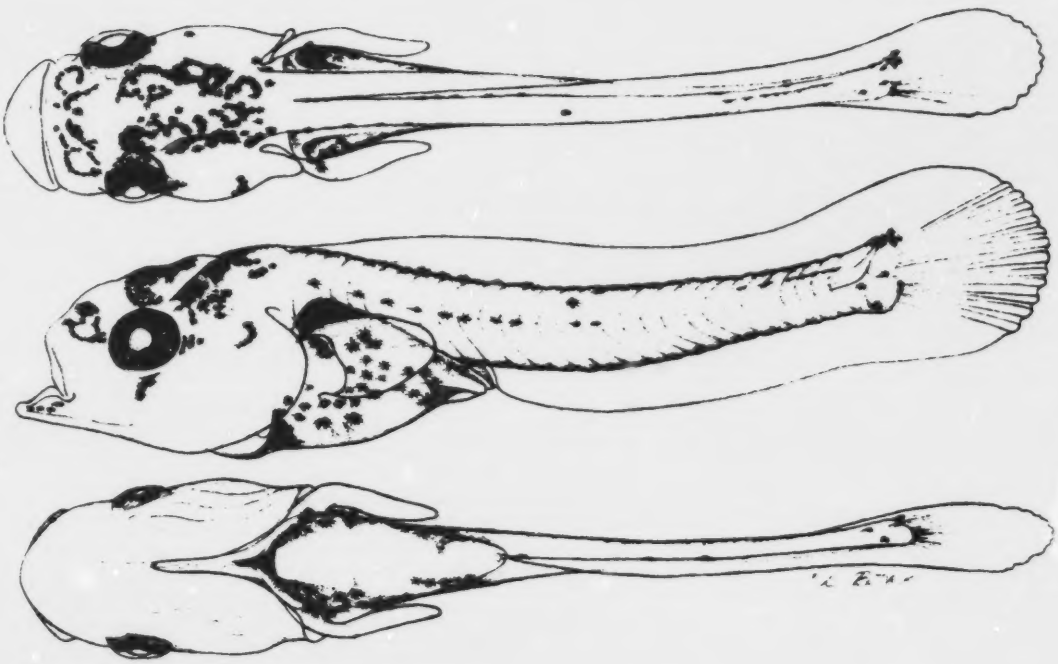

Figure 1. Pirate perch (Aphredoderus sayanus) mesolarvae; dorsal, lateral and ventral views; 5.8 mm TL, 5.1 mm SL. Collected from the Savannah River, South Carolina.

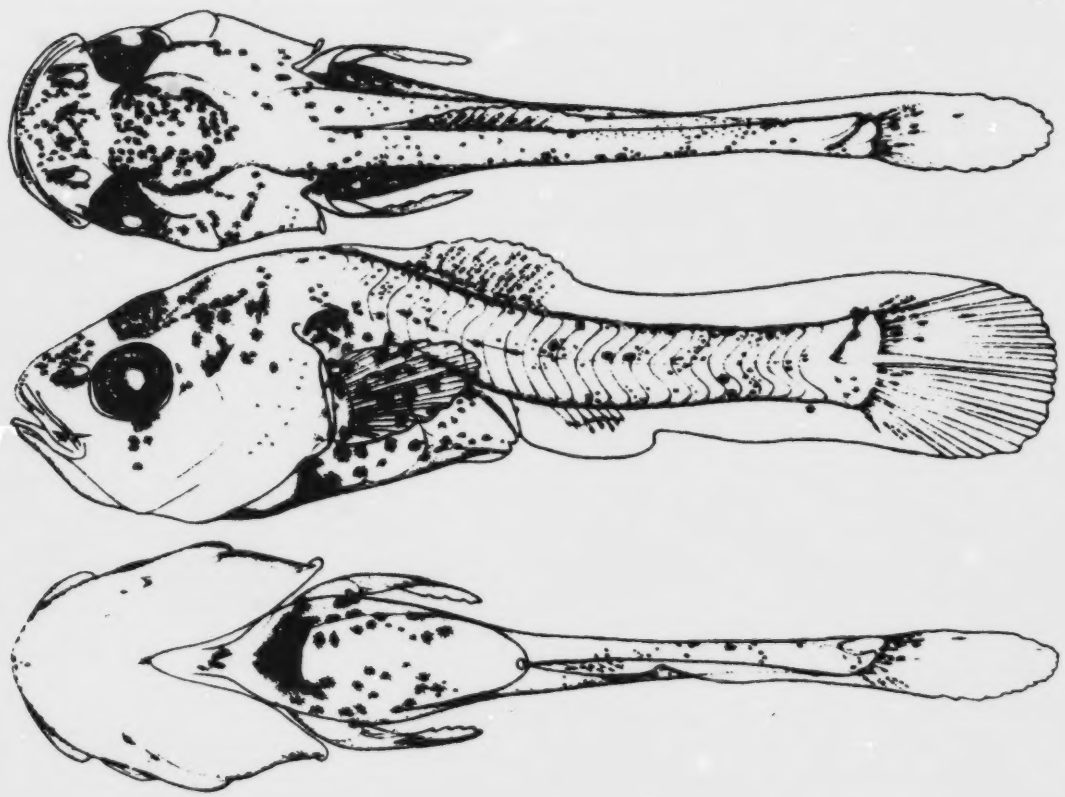

Figure 2. Pirate perch (Aphredoderus sayanus) mesolarvae; dorsal, lateral and ventral views; 7.5 mm TL, 6.2 mm SL. Collected from the Savannah River, South Carolina.

Figure 3. Pirate perch (Aphredoderus sayanus) metalarvae; dorsal, lateral and ventral views; 9.1 mm TL, 7.3 mm SL. Collected from the Savannah River, South Caroina.

ACKNOWLEDGEMENTS

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Larval Ontogeny of the Cypress Darter, *Etheostoma proeliare*

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INTRODUCTION

The cypress darter, *Etheostoma proelaire* is a member of the percid subgenus *Microperca*, and is one of the smallest North American fishes attaining a maximum length of 44 mm (Burr 1978; Kuehne and Barbour 1983). Page (1981, 1983) combined *Microperca* with *Boleichthys* based on morphological characteristics and habitat usage.

The cypress darter ranges from southern Illinois to western Florida, west to east Texas and north to Missouri (Douglas 1974; Pflieger 1975; Smith 1979; Lee et al. 1980). *E. proeliare* is found in Illinois and is locally common in Max Creek, a tributary of Bay Creek, Johnson County (Burr and Page 1978; Smith 1979). In Louisiana it is one of the most abundant and widely distributed darters (Douglas 1974).

The cypress darter inhabits the margins of bayous, swamps, and lakes and the backwaters and pools of sluggish streams and rivers that contain vegetation and accumulated leaves (Douglas 1974; Pflieger 1975; Burr and Page 1978; Smith 1979). Spawning continues from mid-March until early June in Illinois and from early February until mid-May in Louisiana (Burr and Page 1978). No distinction is observed between the habitat usage of larval and adult *E. proeliare* (Burr and Page 1978; present study).

Information on the larval development of the species has been incorporated in a life history study (Burr and Page 1978), and in the description of the distinct egg morphology and its relationship to embryonic development (Burr and Ellinger 1980). Morphological, meristic and pigment characteristics of larval and juvenile *E. proeliare* are described here in order to discriminate between sympatric percids.

METHODS

Descriptions were based on preserved specimens obtained from the Illinois Natural History Survey, Southern Illinois University at Carbondale, and the Department of Fisheries Louisiana State University in cooperation with the Louisiana Cooperative Fishery Research Unit.

The reference collection of larvae was reared from eggs collected on 16 March 1976 from Max Creek, a tributary of Bay Creek (Ohio River drainage), Johnson County, Illinois. Additional larval specimens were obtained from backwater floodplain areas of the Mississippi River near St. Francesville, West Louisiana Parish, Louisiana during the months of April and May 1980. Adults spawned and eggs were incubated in aquaria (Strawn 1956) at constant temperatures at 10°C, 15 °C, 20 °C, and 22 to 23 °C by the Illinois Natural History Survey. Larvae collected from the Mississippi River floodplain were wild caught.

Specimens were preserved in 5 % formalin. A total of 18 eggs and 116 larvae and early juveniles was examined after preservation. Myomeres were counted using polarized light. Preanal myomeres included those anterior to a vertical line drawn from the posterior portion of the anus, while postanal myomere counts included a urostylar segment (Snyder et al. 1977). Total length was measured from the tip of the snout to the tip of the caudal finfold. Standard length was measured horizontally from the tip of the snout to the posterior portion of the notochord. Morphometric measurements were made with a dissecting microscope and ocular micrometer. Measurements were made following Fuiman (1981).

Specimens utilized for vertebrae counts were initially preserved in 10 % formalin then transferred to isopropyl alcohol, cleared and stained using the method of Fritzsche and Johnson (1978), and stored in glycerine.

DESCRIPTIONS

EGGS

The cypress darter and some other percids have an unique egg morphology in that mature ova, including the primary egg envelopes, are deeply indented on one side (Burr 1978; Burr and Page 1978; Burr and Ellinger 1980). This characteristic is shared by other members of the subgenus *Hololepis* (Kuehne and Barbour 1983).

The diameter of ferilized eggs reported in the literature ranges from 0.5 to 1.1 mm (Burr and Page 1978), mature unfertilized egg diameters range from 0.9 to 1.0 mm (Burr and Ellinger 1980). In the present study eggs from Max Creek, Illinois were found to have egg diameters ranging from 0.8 to 1.1 mm ($N = 18$, $\bar{x} = 1.0$ mm). Mature ova of *E. proeliare* are demersal and adhesive, with translucent yolk. They have a single oil globule, a narrow perivitelline space and an unsculptured chorion. Eggs spawned in aquaria were attached to dead leaves, twigs, and the sides and undersides of large rocks.

Eggs incubated at 10°C developed but failed to hatch, while eggs incubated at 15°C hatched at 300 $\pm$ 9 hours, at 20 °C hatching occurred in 211 $\pm$ 23 hours, and at 22 to 23 °C hatching occurred in 131 $\pm$ 9 hours (Burr and Page 1978). Burr and Ellinger (1980), reported hatching occurring after 129 to 130 hours for eggs maintained at temperatures ranging from 26 to 28°C.

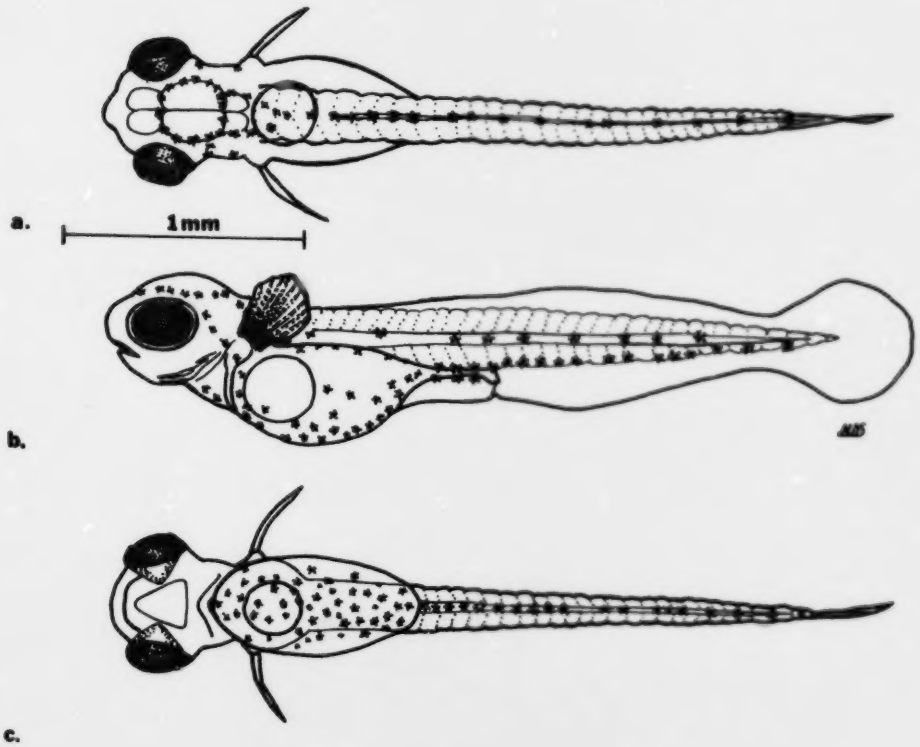

FIGURE 1. *Etheostoma proeliare*, cypress darter (newly hatched larva) 3.3 mm TL, Max Creek, IL (a) dorsal (b) lateral (c) ventral

LARVAE

Morphology

Selected morphometric measurements are highlighted in Table 1. At lenghts 3.2 to 3.5 mm (newly hatched): well developed pectoral fin buds present with 9 incipient rays; first pectoral rays formed (4.2 mm); yolk sac bulbous anteriorly tapering posteriorly; yolk translucent; single anterior oil globule; head not deflected over yolk sac; jaws well developed. Yolk absorbed (ca. 4.2 mm); eyes oblong.

First dorsal rays formed (4.2 to 5.4 mm); incipient dorsal fin margin partially differentiated (ca. 8.3 mm), completely differentiated (10.1 mm), spinous dorsal fin origin over myomeres 4 to 5, soft dorsal origin situated over preanal myomere 14 to 15 (ca. 7.1 mm); predorsal length 26 % of standard length (3.3 to 5.6 mm), 31 % total length (6.5 to 9.9 mm), 14 to 15 % of standard length (13.1 to 23.5 mm); notochord flexion (4.2 to 5.6 mm), prior to first caudal fin ray formation (5.4 to 6.5 mm); caudal fin truncate (7.9 to 9.0 mm); first anal fin ray formed (ca. 6.3 mm); incipient anal fin margin partially differentiated (ca. 8.8 mm), completely differentiated by 9.9 mm; pelvic buds formed anterior to dorsal fin origin (ca. 8.3 mm); first pelvic fin rays formed (8.4 mm). No swim bladder formed; gut straight; entire finfold absorbed (ca. 8.9 mm).

Supraorbital and infraorbital head canals started forming (9.9 to 10.8 mm), supraorbital and infraorbital head canals completely formed (10.1 to 10.9 mm), infraorbital canal complete without interuption and pore count of 10 (ca. 9.9 mm) retrogression to interupted pore count of 1 posterior and 3 anterior (ca. 17.6 to 19.4 mm); preoperculomandibular and supratemporal canal began forming (ca. 12.1 mm), completely formed (14.8 to 17.1 mm); lateral line began forming 14.1 mm; scales started to form on operculum (ca. 12.7 mm), scales formed on operculum (ca. 14.9 mm); scales formed on cheeks (20.6 to 21.5 mm). Mandible and maxillary of equal lengths extending past anterior portion of orbit (at all lengths).

TABLE 1. Morphometry of *Etheostoma proeliare* larvae and early juveniles grouped by 1 mm intervals of total length (N = sample size). Mean lengths followed by range in parentheses.

	LENGTH (mm)								
N	TOTAL	STANDARD	PREANAL	HEAD	SNOUT	EYE	BODY DEPTH[a]	GREATEST[b]	CAUDAL PEDUNCLE[c]
10	3.3(3.2-3.8)	3.2(3.0-3.6)	1.6(1.5-1.9)	0.5(0.46-0.6)	0.07(0.06-0.1)	0.2(0.2-0.25)	0.24(0.2-0.3)	0.6(0.56-0.7)	0.13(0.12-0.16)
1	4.2	4.0	2.0	0.75	0.16	0.3	0.3	0.6	0.16
7	5.6(5.2-5.9)	5.3(5.0-5.5)	2.6(2.5-2.8)	1.0(0.9-1.1)	0.18(0.15-0.2)	0.4(0.37-0.4)	0.4(0.38-0.4)	0.8(0.79-0.9)	0.22(0.20-0.22)
7	6.4(6.1-6.7)	6.1(5.9-6.2)	3.0(2.9-3.2)	1.1(1.0-1.3)	0.20(0.15-0.3)	0.45(0.43-0.48)	0.5(0.48-0.5)	0.9(0.9-0.92)	0.26(0.22-0.30)
4	7.5(7.1-7.9)	6.6(6.3-6.7)	3.5(3.3-3.7)	1.3(1.2-1.4)	0.28(0.27-0.3)	0.5(0.5-0.55)	0.8(0.8-0.9)	1.1(1.0-1.2)	0.43(0.35-0.49)
10	8.5(8.0-8.8)	7.2(6.8-7.5)	4.0(3.8-4.2)	1.7(1.6-1.8)	0.36(0.3-0.4)	0.58(0.56-0.6)	0.9(0.85-1.1)	1.3(1.1-1.4)	0.53(0.46-0.60)
1	9.9	8.8	4.6	2.7	0.44	0.7	1.1	1.7	0.7
6	10.5(10.0-10.8)	8.8(8.5-9.2)	4.9(4.7-5.2)	2.6(2.3-2.7)	0.40(0.38-0.6)	0.7(0.6-0.7)	1.3(1.1-1.4)	1.4(1.4-1.5)	0.77(0.6 -0.85)
4	11.7(11.5-11.9)	9.8(9.5-10.2)	5.4(5.2-5.7)	2.9(2.8-3.1)	0.55(0.50-0.56)	0.74(0.7-0.8)	1.5(1.5-1.6)	1.7(1.5-1.9)	0.93(0.92-0.96)
10	12.6(12.1-12.9)	10.5(9.9-11.0)	5.7(5.2-6.0)	3.0(2.7-3.2)	0.55(0.46-0.65)	0.76(0.73-0.77)	1.6(1.5-1.7)	1.9(1.9-2.2)	0.96(0.88-1.04)
4	13.6(13.5-13.9)	11.2(11.1-11.4)	6.1(5.9-6.3)	3.1(3.1-3.1)	0.60(0.46-0.77)	0.78(0.77-0.81)	1.7(1.7-1.9)	2.1(2.0-2.3)	1.06(1.00-1.10)
4	14.3(14.1-14.8)	11.8(11.6-12.2)	7.0(6.9-7.0)	3.5(3.4-3.6)	0.66(0.65-0.68)	1.00(1.00-1.04)	1.7(1.7-1.76)	2.3(2.2-2.36)	1.00(1.00-1.04)
1	15.6	12.9	7.6	3.8	0.66	1.1	1.85	2.5	1.1
5	16.2(16.0-16.5)	13.4(13.3-13.6)	7.9(7.4-8.3)	4.0(3.8-4.2)	0.65(0.60-0.68)	1.05(1.0-1.08)	1.96(1.8-2.16)	2.6(2.5-2.8)	1.2(1.1-1.4)
6	17.5(17.2-17.8)	14.3(14.0-14.7)	8.0(7.7-8.4)	4.2(3.8-4.4)	0.81(0.72-0.84)	1.1(1.1-1.2)	2.3(2.2-2.4)	2.8(2.6-3.2)	1.4(1.3-1.4)
7	18.6(18.2-18.9)	15.1(14.9-15.2)	8.6(8.4-8.8)	4.4(4.0-4.8)	0.85(0.72-0.92)	1.2(1.1-1.3)	2.4(2.2-2.6)	3.0(2.7-3.2)	1.5(1.4-1.6)
4	19.2(19.0-19.4)	15.8(15.6-16.1)	8.9(8.5-9.3)	4.6(3.6-4.8)	0.81(0.72-0.88)	1.1(1.1-1.2)	2.3(2.1-2.4)	3.0(2.7-3.0)	1.4(1.4-1.5)
11	20.4(20.2-20.6)	16.7(16.4-17.1)	9.5(9.0-10.6)	4.8(4.0-5.4)	0.87(0.72-1.00)	1.2(1.1-1.4)	2.5(2.2-2.8)	3.1(3.0-3.2)	1.5(1.3-1.6)
12	21.4(21.1-21.9)	17.6(17.0-18.0)	9.8(9.3-10.2)	5.0(4.5-5.4)	0.89(0.84-1.00)	1.3(1.2-1.4)	2.7(2.2-2.8)	3.3(2.8-3.5)	1.6(1.4-1.8)
1	22.4	18.3	10.5	5.4	0.92	1.4	3.2	3.6	1.8
1	23.5	19.3	10.6	5.7	0.92	1.4	3.2	3.6	1.7

(a) Body depth measured vertically from the dorsal to ventral surface at posterior portion of anus

(b) Greatest body depth measured vertically from dorsal to ventral surface including the yolk sac

(c) Caudal peduncle depth measured vertically from the dorsal to ventral surface at penultimate myomere

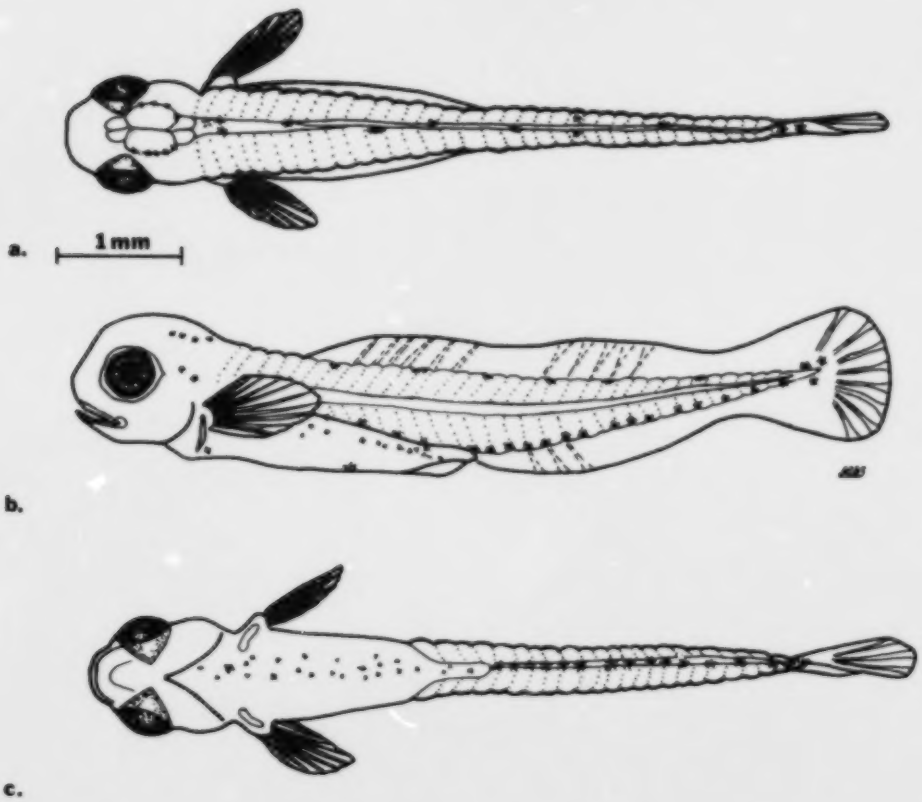

FIGURE 2. *Etheostoma proeliare*, cypress darter larva 6.5 mm TL, lower Mississippi River, LA (a) dorsal (b) lateral (c) ventral

Meristics

Myomere number constant posthatching, preanal myomeres 15, postanal 19 to 20 with 34 to 35 total. Total vertebrae numbering 35 to 36; N = 4, $\bar{x}$ = 35.3, including one urostylar element, from specimens collected in Max Creek, Johnson County, Illinois (20.6 to 21.9 mm). Scales in the lateral series ranging from 32 to 39 (N = 48, $\bar{x}$ = 36.3, mode = 37). Paired and median fin ray values and length at appearance are presented in Table 2.

Pigmentation

Length 3.2 to 3.5 mm (newly hatched): moderately pigmented (Fig. 1); retinae black; concentration of melanophores on dorsal portion of cranium outlining the optic lobe and tapering into a point around the cerebellum; a single line of melanophores dorsally from the occiput to the tip of the caudal peduncle; two oblique parallel series of melanophores laterally extending from the posterior portion of the orbit into the anterior and posterior sections of the yolk sac. A midlateral stripe consisting of a single melanophore at the anterior apex of preanal myomere 2 through 12 alternating every fifth

TABLE 2. Selected meristic values and size (mm TL) at the apparent onset of development for *Etheostoma proeliare*. Means and modal values are underscored. Rare or questionable extremes are in parentheses. The number of secondary rays of the median fins are in lowercase Roman numerals.

Attribute/Event	Present Study	Literature[a]
Dorsal Fin Spines/Rays	VII-VIII / 9-10	VII-VIII-II / 8-11-13 [3,5-8]
first rays formed	4.2	no information
adult complement formed	8.9	no information
Anal Fin Spines/Rays	I / 5-6	I-II / 6-7 [3,5-8]
first rays formed	6.3	no information
adult complement formed	>9.9	no information
Caudal Fin Rays	viii-xiv, 6-8 + 8, viii-xii	9-10-11-12 [4,5]
first rays formed	5.4	no information
adult complement formed	7.7	no information
Pectoral Fin Rays	9 - 10	8-9-10-11-13 [5,7,8]
first rays formed	3.8	3.5 [9]
adult complement formed	4.7	no information
Lateral series-scales	32-39	32-35-36-38 [2,3,5-9]
Myomeres/Vertebrae	34-35/35-36	no information/32-35-36-38 [1,5-8]
preanal myomeres	15	no information
postanal myomeres	19-(20)	no information

(a) 1. Gosline 1965, 2. Douglas 1974, 3. Pflieger 1975, 4. Robison 1977, 5. Burr 1978, 6. Smith 1979, 7. Page 1983, 8. Kuehne and Barbour 1983 9. Burr and Ellinger 1980

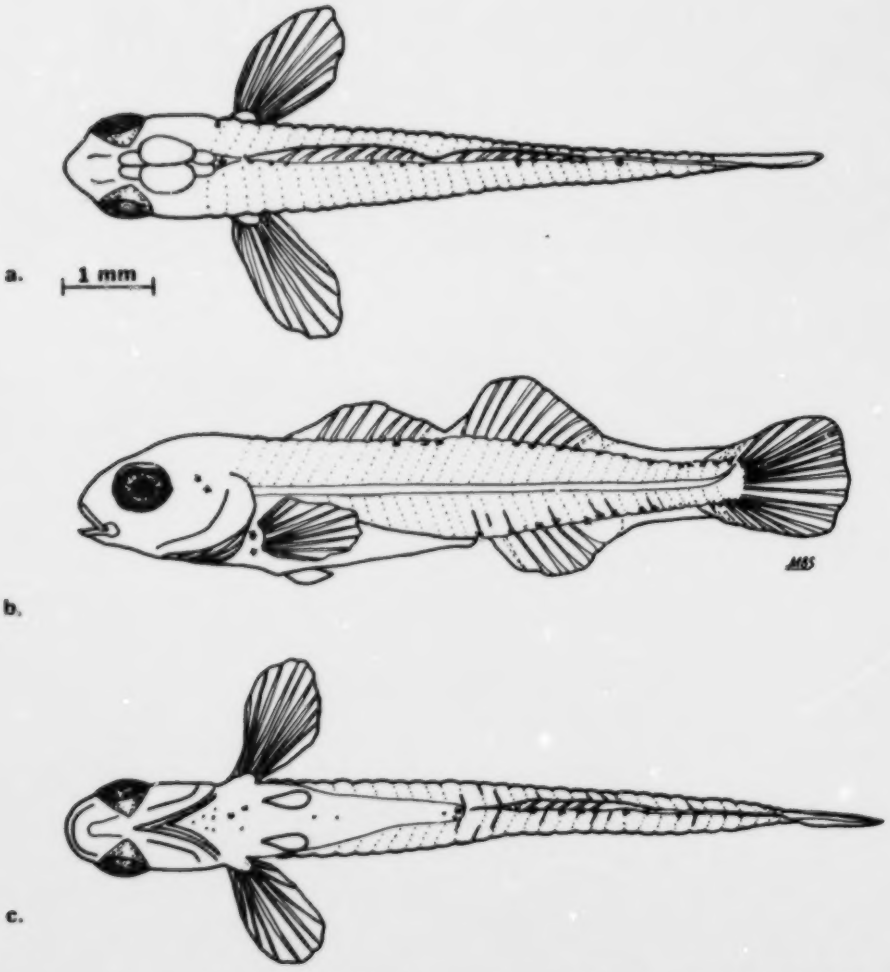

FIGURE 3. *Etheostoma proeliare*, cypress darter larva 8.3 mm TL, lower Mississippi River, LA (a) dorsal (b) lateral (c) ventral

myoseptum and every third myoseptum from the anus to postanal myomere 14. Melanophores around anus ventrally and over the yolk sac dorsally; ventrally a single melanophore at anterior margins of postanal myomere 1 through 6, 8 and 9, 11 through 13, then alternating thereafter.

Length 4.2 mm: eyes black; dense occipital pigmentation; dorsally, a single row of melanophores from the nape to the end of the caudal fin. A single diagonal line of melanophores extending from the orbit through the cleithra; dense dermal and subdermal pigment on the ventral portion of the yolk sac; pigment little to entirely absent dorsally on gut; pigment outlining dorsally and ventrally the anus from the stomach posteriad. Midlateral stripe of single melanophores at posterior part of myosepta from preanal myomeres 8 to 13, and located every other myoseptа on postanal myosepta 1 to 9. Ventrally, melanophores located on postanal myomeres 5 to 14 and at the tip of the caudal peduncle.

Length 6.4 to 8.5 mm: oblique line separated into several melanophores posterior to orbit and several others on cleithra. Melanophores dorsally forming eight distinct areas of concentration (less apparent forming a straight line from 6.4 to 7.1 mm). Subdermal pigment concentrated ventrally under stomach; several melanophores ventrally forming a straight row between the cleithra to the center of the stomach. Melanophores located at tip of caudal peduncle near differentiating caudal fin (Fig. 2). Pigment patterns were essentially unchanged for the duration of the larval period, with patterns less prominent after 8.3 mm TL (Fig. 3).

Length 9.9 mm: melanophores dorsally concentrated over cerebrum, optic lobe, and cerebellum; suborbital tear drop forming, as well as preorbital and postorbital bars; melanophores forming a half circle on ventral portion of opercle. A single midlateral stripe of

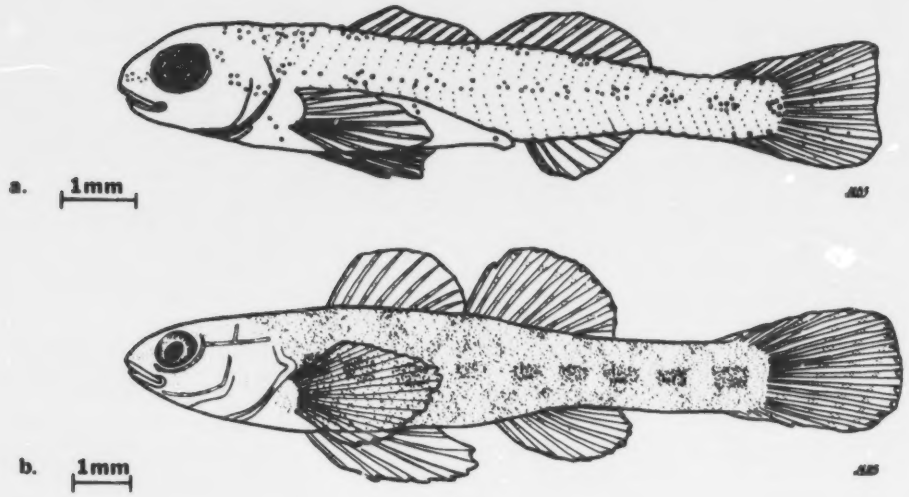

FIGURE 4. *Etheostoma proeliare*, cypress darter, (a) larva 9.9 mm TL, Max Creek, IL (b) early juvenile 13.5 mm TL, Max Creek, IL

melanophores from the anterior margin of the pectoral fin posterially to the caudal peduncle forming 11 lateral blotches; ventrally melanophores concentrated in a single row from the articulation of the pectoral fin posteriad to anus. Specks of melanophores at distal half of pectoral fins; two oblique rows of melanophores forming stripes in the spinous and soft dorsal; two diagonal rows of melanophores forming stripes in caudal fin (Fig. 4a).

Length 10.2 to 11.8 mm: preorbital, postorbital and suborbital bars chevron shaped; melanophores extending oblique ventrally from the midpoint of the orbit on opercle. A midlateral concentration of melanophores forming 9 to 11 lateral blotches; dorsally 8 to 9 saddles; several clusters of ventral melanophores on breast and further posterior with a single line of pigment in between; posteriorly a single line of melanophores ventrally from the anus to caudal peduncle expanding into a small cluster at the tip. Specks of melanophores scattered in between pectoral fin rays; dorsal spinous and soft rays each with 2 oblique stripes; caudal fin with four diagonal stripes.

Length 13.5 to 14.2 mm (juveniles): preorbital bar extending to tip of snout; dorsal section of cranium well pigmented; scattered pigment connecting 9 to 11 rectangular midlateral blotches to 8 or 9 dorsal saddles; scattered melanophores extending ventrally connecting lateral blotches; a vertical stripe at the posterior margin of the caudal peduncle bisecting the last rectangular blotch; outline of scales pigmented; melanophores ventrally at pteriogiophore interdigitation with lepidotrichia of anal fin only. Entire pectoral fin with scattered melanophores on membranes; 3 oblique stripes of clustered melanophores on the spinous and soft dorsal (pigmented directly on the ray); anal fin with a single stripe; caudal fin with 4 diagonal stripes on membrane (Fig. 4b).

DISCUSSION

Seven darter species inhabit the Bay Creek system with only two occurring sympatrically in Max Creek. The bluntnose darter, *E. chlorosomum* and slough darter, *E. gracile* are common in the study area. The rainbow darter, *E. caeruleum*; johnny darter, *E. nigrum*; stripetail darter, *E. kennicotti*; orangethroat darter, *E. spectabile*; and blackside darter, *Percina maculata* all occur in the Bay Creek system (Burr and Page 1978). In Louisiana, the cypress darter occurs in all drainages of the state where percid species have been collected although not always in similar microhabitats (Douglas 1974).

Larvae of the cypress darter can be distinguished from other percids by the low preanal and postanal myomere counts and the pigmentation pattern. Confusion with other members of the genus *Etheostoma* can be avoided if the unique cranial pigment pattern is taken into consideration. The two oblique parallel series of melanophores extending from the orbit posterior into the anterior and posterior sections of the yolk sac, the encircling of the optic lobe by melanophores, in combination with the midlateral stripe and ventral postanal pigment makes the cypress darter unique from many other darter species whose larvae are known.

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The larvae and juveniles of Cottus ricei and sympatric Cottidae

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ABSTRACT

Metalarvae and juveniles of Cottus ricei were collected from the Eastmain River and Estuary, on the east coast of James Bay, Quebec. The specimens were readily distinguished from other cottid species within their range by the presence of prickles (small bony spines) along both sides of the dorsal and anal fins of metalarvae and over most of the body of juveniles. This material coupled with other recent contributions to our knowledge of cottid larvae lead to a reassignment of several early descriptions of Lake Erie fish larvae to C. ricei.

Among the cottids of the interior waters of Canada, C. ricei hatch as protolarvae at less than 7 mm TL (total length), probably with moderate-size yolk sacs, while C. bairdi and C. cognatus hatch at about 6 or 7 mm TL as very late protolarvae, or as mesolarvae, with large yolk sacs. C. ricei mesolarvae bear little if any yolk while C. bairdi and C. cognatus retain large yolk sacs until the beginning of the metalarval phase. Myoxocephalus thompsoni and M. quadricornis are suspected to hatch at about 7 to 9 mm TL with moderate-size yolk sacs and remain protolarvae until 10 or 11 mm TL, by which size the Cottus species are already metalarvae.

INTRODUCTION

Cottus ricei (spoonhead sculpin) is an inhabitant of the Great Lakes and the rivers, lakes, and occasionally estuarine and brackish waters of much of interior Canada from the St. Lawrence drainage northwest to the mouth of the MacKenzie River (Scott and Crossman 1973, Lee et al. 1980). It is sympatric throughout its range with the more broadly distributed Cottus cognatus (slimy sculpin) and in the southern and eastern portions of its range with Cottus bairdi (mottled sculpin). In the Great Lakes and some of the deeper, cooler, inland lakes of its range it is sympatric with Myoxocephalus thompsoni (deepwater sculpin). In the estuarine and brackish waters of James Bay and probably the estuaries of southwestern Hudson Bay and the MacKenzie River, its range is also occupied by Myoxocephalus quadricornis (fourhorn sculpin).

Scott and Crossman (1973) considered C. ricei "the most distinctive member of the genus Cottus in North America." However, no published descriptions of the larvae or early juveniles, apart from that of a 27.5 mm specimen described and illustrated by Fish (1932), were recognized prior to Heufelder (1982). Heufelder (1982) illustrated and described C. ricei larvae measuring 7 to 11 mm TL as well as a 21.5 mm TL juvenile. He also included data on the 27.5 mm juvenile described by Fish (1932) and noted that Fish's descriptions and illustrations of C. bairdi larvae (6 to 11 mm TL) might have been based on misidentified C. ricei. Khan and Faber (1974) had previously reassigned those same C. bairdi descriptions to the freshwater form of Myoxocephalus quadricornis, now recognized as M. thompsoni (Robins et al. 1980). Snyder and Douglas (1978), who also recognized that Fish's (1932) descriptions were not of C. bairdi, were in turn suspicious of Khan and Faber's alternative identification. All the above mentioned descriptions were based on field-collected specimens from Lake Erie (Fish's descriptions) and Lake Superior (original descriptions by Heufelder).

Heufelder (1982) also included descriptive accounts of the larvae and juveniles of C. bairdi (6 to 15 mm TL) and C. cognatus (6 to 11 mm TL) based in part on Heufelder and Auer (1980), Khan (1971), Koster (1936), and Van Vliet (1964); and the larvae of M. thompsoni (10 to 18 mm TL) based in part on Khan (1971) and Khan and Faber (1974). The latter two authors also covered the larvae of M. quadricornis. Heufelder (1982) questioned the identity of 12.5 and 16.2 mm TL M. thompsoni (Triglopsis thompsoni) described by Fish (1932) and suggested they might be C. bairdi. Descriptions by Fish (1932) of a 19.0 mm TL C. bairdi, and 18 and 21.5 mm TL C. cognatus remained undisputed in the published literature. Some of the descriptions and illustrations in Fish (1932) were previously published in Fish (1929); for convenience we refer only to the former in this paper.

Our primary purpose in this paper is to fill critical voids in recognized accounts of C. ricei larvae and juveniles by providing original descriptive data and illustrations and by reassignment of previously published

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descriptions. Our second objective is to compare C. ricei larvae and juveniles with those of sympatric cottids to illucidate and confirm diagnostic characters.

MATERIALS AND METHODS

Young-of-the-year C. ricei were collected, along with other cottids, from May to September 1980 in the lower portion of the Eastmain River and its estuary on the east shore of James Bay, Quebec (Ochman and Dodson 1983). The specimens were fixed and preserved in 5% buffered formalin. Measurements were made to the nearest tenth of a millimeter under dissecting microscopes fitted with ocular micrometers. Specimen lengths reported in the text are total lengths. Fin ray and myomere counts were verified by clearing selected specimens in 5% KOH and staining the bone with alizarin red. For comparative purposes, the morphometric and meristic characters utilized in our study of C. ricei include those recorded for cottids by Heufelder and Auer (1980) and Heufelder (1982). Additional data were summarized from the literature and original observations on the larvae and juveniles of other species from various sources. Developmental phase terminology follows Snyder (1976, 1981).

RESULTS AND DISCUSSION

DESCRIPTION OF METALARVAE AND JUVENILES FROM EASTMAIN RIVER AND ESTUARY

Specific length measures for these specimens are graphed in Figure 1. These data as well as data on meristics (countable structures) and size at the onset of selected developmental events are summarized and combined with

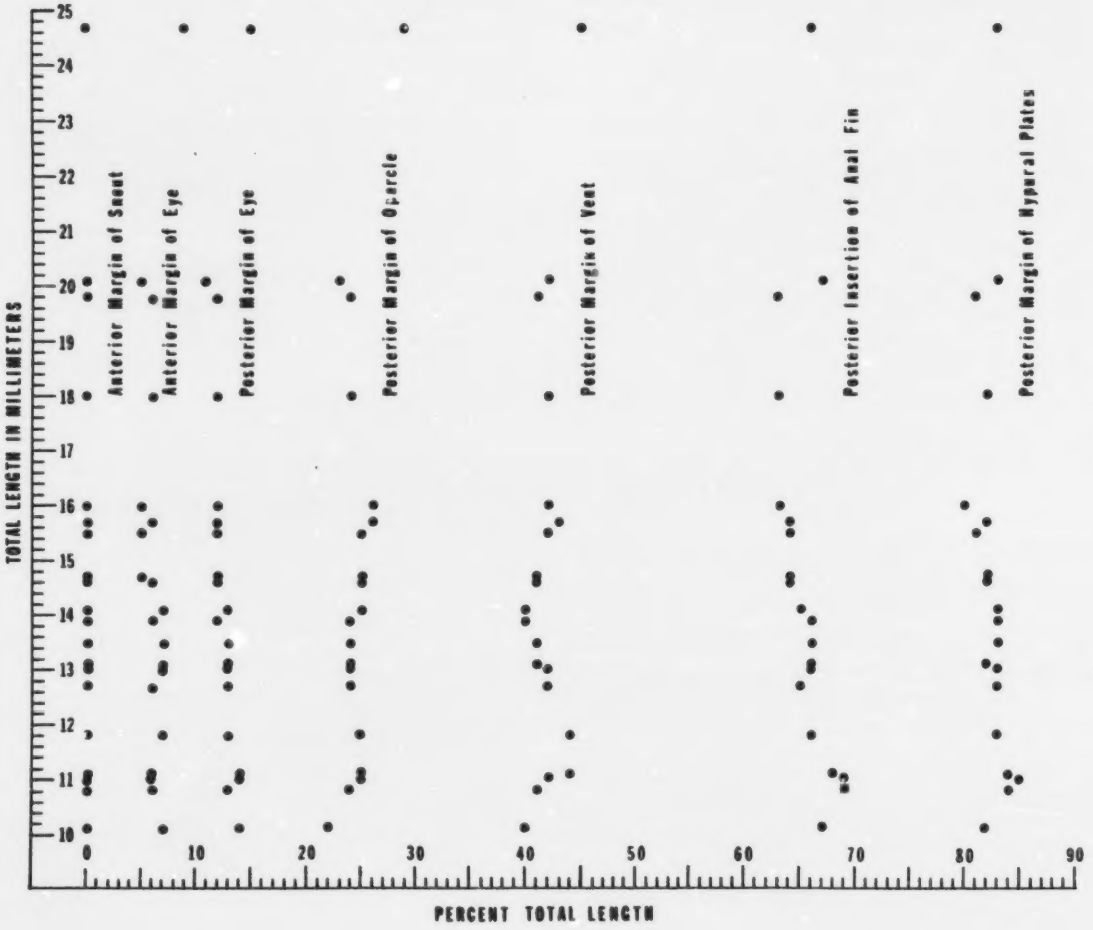
TOTAL LENGTH IN MILLIMETERS
PERCENT TOTAL LENGTH
Anterior Margin of Snout
Anterior Margin of Eye
Posterior Margin of Eye
Posterior Margin of Opercle
Posterior Margin of Vent
Posterior Insertion of Anal Fin
Posterior Margin of Hypural Plates

Figure 1. Proportional lengths to selected structures or points for Cottus ricei metalarvae and early juveniles from the Eastmain River and Estuary, James Bay, Quebec.

previously published data in Tables 1, 2, and 3 for comparison with sympatric cottids.

Even the smallest C. ricei collected, about 10 mm, are without yolk and possess a full complement of adult fin elements except for the procurrent caudal rays. The smallest specimens also have a finfold anterior to the developing procurrent rays (Figure 2). The adult count of procurrent caudal rays is attained by 11 to 12 mm but the metalarval phase continues until the finfold is lost, at about 13 mm.

C. ricei juveniles have a slender elongate body and head flattened in profile but wide and spatulate when viewed from above. From a terminal mouth, the dorsal profile rises gently to the back of the head and is slightly depressed between small dorsally oriented eyes. The gill membrane is broadly attached to the isthmus. A long, backward-extending, but upwardly-curved preopercular spine, and three

Table 1. Summary of selected morphometric data by developmental phase or period for larvae (Pr-protolarvae, Ms-mesolarvae, Mt-metalarvae) and juveniles (Jv) of Cottus ricei and sympatric cottids.

Species:		Cottus ricei	Cottus bairdi	Cottus cognatus	Myoxocephalus thompsoni	Myoxocephalus quadricornis
Sources of data[a]:		H,F,O	A,H,O	A,H,O	H,K	K
Maximum number of specimens examined or reported (number of illustrations from which additional data was extracted in parentheses)	Pr	1(1)	-[b]	≥2(1)[b]	≥2(1)	-
	Ms	≥3(3)	≥2(1)	≥2(1)	≥2(3)	-(1)
	Mt	≥10(7)	≥20(3)[c],	≥22(2)[c]	≥2(1)	-(2)
	Jv	18(4)	5	7(1)	-	-
Total lengths, millimeters	Pr	7	-	6	8-10	-
	Ms	6-8	6-7	6-8	10-15	13
	Mt	9-13	7-15[c]	7-14[c]	15-18	14-17
	Jv	13-28	16-23	18-26	-	-
Lengths, %total length:						
Standard	Pr	96	-	95-98	93-98	-
	Ms	93-99	91-94	78-92	93-97	95
	Mt	81-95	82-90	80-89	93-96	88-91
	Jv	78-88	-	78-83	-	-
Snout-to-vent	Pr	39-42	-	44-49	36-38	-
	Ms	42-47	45-54	46-50	38-42	35
	Mt	39-47	42-52	39-48	40-43	35-40
	Jr	40-45	-	43-44	-	-
Head	Pr	16-17	-	17-20	14-17	-
	Ms	16-22	18-25	22-25	16-20	16
	Mt	18-26	18-26	18-27	20-26	20
	Jv	20-29	23-28	24-28	-	-
Yolk sac	Pr	-[d]	-	28-33	14[d]	-
	Ms	-[d]	32-37	28[d]	-	-
	Mt	-	27-31[d]	-[d]	-	-
Caudal peduncle	Ms	-	-	18	33	-
	Mt	13-27	13-15	13-20	30	21-30
	Jv	11-19	-	10	-	-
Lengths, % head length:						
Eye	Pr	26-27	-	35-41	40-54	-
	Ms	27-42	31-41	29-44	27-35	36
	Mt	18-36	28-39	27-41	30	32
	Jv	18-30	25-31	25-38	-	-
Postorbit head	Pr	44-47	-	43	43	-
	Ms	32-46	54	62	31-48	46
	Mt	36-54	35-54	37-50[e]	43	42-43
	Jv	42-55	-	45-49	-	-

[a] A-Heufelder and Auer (1980), Fish (1932, including reassigned descriptions), H-Heufelder (1982), K-Khan and Faber (1974), O-Original observations.

[b] This species either hatches as a mesolarva or achieves that state very shortly after hatching.

[c] Largest specimens might qualify as juveniles if caudal finfold has been lost.

[d] Yolk present in some or additional specimens but either not measured or too little to measure accurately.

[e] Does not include datum for 7.9 mm specimen erroneously calculate in Heufelder (1982) from Heufelder and Auer (1980 -- 35% value should be 44%.

smaller preopercular spines below and oriented downward, are easily seen even in the smallest specimens examined. In larger specimens (17 mm) the smallest spines become partially overgrown with skin.

Small bony prickles, usually directed backward, are present on the bodies of all specimens (Figure 2). Those measuring 10 to 13 mm have two solitary series of prickles along both the dorsal and ventral surfaces. The dorsal series begin as a patch behind the head and extend with one series along each side of the dorsal fin, to the last myomere. Likewise, the two ventral series extend from the vent to the last myomere along each side of the anal fin and ventral midline of the caudal peduncle. Juveniles between 13 and 15 mm have additional series of prickles on their lateral surfaces. Larger specimens are covered densely with prickles or small spines on the entire body posterior to the head.

Body pigmentation is faint on the smallest specimens, but quite prominent shortly after transition to the juvenile period with four or five irregular, saddle-like, dorsal to lateral splotches and a broad band or splotch at the base of the caudal fin (Figure 2). Most specimens exhibit a series of melanophores

Table 3. Summary of size, in millimeters total length, at the apparent onset of selected developmental events for larvae of Cottus ricei and sympatric cottids based on a combination of original observations and data reported in literature. Rare or questionable extremes are enclosed in parentheses.

Species:	Cottus ricei			Cottus bairdi	Cottus cognatus	Myoxocephalus thompsoni	Myoxocephalus quadricornis
Source of Data [a]:	H,O	F	Combined	A,H,O	A,H,O	H,K	K
Events							
Hatching:	<7	≤6	≤6	6-7	6	≤8	<12
Eyes pigmented:	<7	≤6	≤6	Embryo	Embryo	≤8	<12
Pectoral fin bud formation:	<7	≤6	≤6	Embryo	Embryo	≤8	<12
Pelvic fin bud formation:	9	<10	9	7	(6) 7 (8)	10-11	<12
Yolk completely absorbed:	8	(6) 7	(6) 7-8	8-10	8-9	10	<12
Finfold completely absorbed:	13		13	14-15[b]	(11) 14-15[c]	>18	>17
First body prickles:	10-12	11-12	10-12	<17[d]	10-12		
First pigment on dorsal surfaces:	10-11	11	10-11	Embryo-6-7	7	≥10-12	≥12
First fin rays -							
Caudal, principal:	7	(6) 7	(6) 7	Embryo-6-7	6-7	(10) 11	≥12
Caudal, procurrent:	(9) 10		(9) 10	8-9	7-8(9)	(12) 14-16	14-15
First Dorsal:	(9) 10	10-11	(9) 10-11	7	7	15-16	15 (16)
Second Dorsal:	(8) 9	>7, <10	(8) 9	7	6-7	12-13	≥12-14
Anal:	(8) 9	>7, <10	(8) 9	7	6-7	12-13	≥12-14
Pectoral:	≤7	>7, <10	7 (8)	Embryo-6-7	Embryo-6	10-11	≥12-14
Pelvic:	10	>7, <10	(9) 10	(7) 8	7-8	17-18	(16) 17
Full complement of fin rays -							
Caudal, principal:	9	<10	9	7	7	13-15	14-15
Caudal, procurrent:	11-12		11-12	11[e]	<12	>18	>17
First Dorsal:	10-11	11	10-11	8	7-8	≥16-17	>17
Second Dorsal:	9	>7, <10	9	7 (8)	(6) 7	14-15	(12) 13-14
Anal:	9	>7, <10	9	7 (8)	(6) 7	14-15	(12) 13-14
Pectoral:	7	>7, <10	7-8	(7) 8	(7) 8	12-14	14 (15)
Pelvic:	10-11	11	10-11	Embryo-6-7	7	≥10-12	≥12

[a] A-Heufelder and Auer (1980), F-Fish (1932, descriptions reassigned to Cottus ricei), H-Heufelder (1982), K-Khan and Faber (1974), O-Original observations.

[b] Lake Michigan specimens; Colorado specimens about 13mm TL.

[c] The 11 mm value was reported by Heufelder (1982) for Lake michigan specimens; the 14-15 mm values are based on original observations on Eastmain River or Estuary specimens.

[d] No prickles were obseved on young-of-the-year juveniles from Colorado, some of which were much larger in size

[e] Colorado specimens.

Table 2. Summary of selected meristics for Cottus ricei and sympatric cottids based on a combination of original observations and data reported in literature. Mean or modal values are underscored if notable. Rare or questionable extremes are enclosed in parentheses. Myomere counts are based on larvae and early juveniles; other counts are based on juvenile and adult observations.

Species: Source of Data[a]:	Cottus ricei	Cottus ricei	Cottus bairdi	Cottus cognatus	Myoxocephalus thompsoni	Myoxocephalus quadricornis
Attribute	F1	F2,H	A,H,M,S,O	A,F2,H,M,S,O	H,K,S	K
Myomeres[b],						
Preanal:	12-13	(11)12-13-14	9-11(12)	(9)10-12(13)	11-12	
Postanal:	20-21-22	20-21-22-23	(19)20-21	19-20(21)	24-26	
Total:	32-33-34-35	(31)32-33-35	(28)29-31-32	(28)29-30-31-32(33)	(33)35-39-42	41-46
Vertebrae:		34-35	31-32-33	31-32-33(35)	37-39	
Fin Meristics[c],						
1st Dorsal:	VII-VIII	VII-VIII-IX (X)	VII-VIII (IX)	(VI) VII-VIII-IX	VII-VIII-IX (X)	
2nd Dorsal:	16-19	15-16-18-19(20)	15-17-18(19)	(14)15-16-17-18(19)	11-13-14-16	13-16
Anal:	12-15	(11)12-14-15(16)	(10)11-13-14-15(16)	10-11-12-13(14)	(11)12-13-14-15(18)	14-17
Caudal:	viii-ix-12-13,viii-ix		viii-ix,12,vii-ix[d]	vi-viii,12,v-vii		
Pectoral:	15	14-16	(12)13-15(17)	(12)13-14-15(16)	(15)16-18	15-16-17
Pelvic:	I,4(3)	I,4	I,4(3)	I,3(4)	I,3(4)	

[a] A - Heufelder and Auer (1980), F1 - Fish (1932, descriptions reassigned to Cottus ricei), F2 - Fish (1932, other descriptions), H - Heufelder (1982), K - Khan and Faber (1974), M - McAllister (1964), S - Scott and Crossman (1973), and O - Original.

[b] Counts from Fish (1932) adjusted + 2 for preanal and - 2 for postanal myomeres to approximate Siefert (1969) approach used by most current biologists.

[c] Spines - upper case Roman numerals; secondary or procurrent rays - lower case Roman numerals; principal soft rays of median fins and all rays of paired fins - Arabic numerals.

[d] Original observations from Lake Ontario specimens; Colorado specimens examined have fewer procurrent caudal rays (v-vii, 12, v-viii).

Table 4. Reassignment of descriptions by Fish (1932) to Cottus ricei.

Original Identification	Total Length (mm)	Text (Page #) (Page #)	Illus-trations (Fig. #)
Cottus bairdii bairdii*	6.0	389-390	133
Cottus bairdii kumlieni	6.6	387	128
Cottus bairdii kumlieni	7.2	387-388	129
Cottus bairdii kumlieni	10.0	388	130
Cottus bairdii kumlieni	10.0	388	131
Cottus bairdii kumlieni	11.0	388-389	132
Triglopsis thompsoni	12.5	385-386	125-126
Triglopsis thompsoni	16.2	386	127

* Tentative

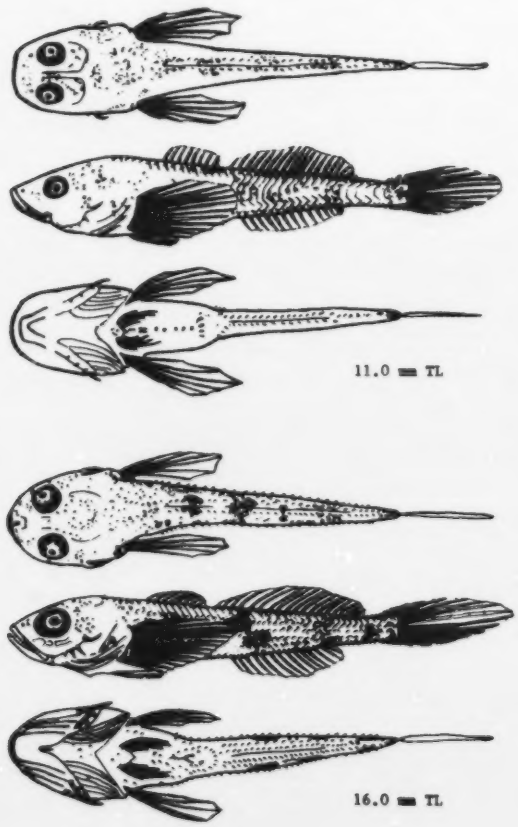

Figure 2. Cottus ricei from the Eastmain River or Estuary, James Bay, Quebec. Dorsal, lateral and ventral views of metalarva (11 mm TL) and juvenile (16 mm TL).

(sometimes just a few) from the pelvic girdle to the vent, usually ending in an irregular aggregation or short perpendicular line of melanophores. Another midline series of melanophores can sometimes be observed deep in the tissues under the anal fin and ventral surface of the caudal peduncle.

REASSIGNMENT OF DESCRIPTIONS BY FISH (1932) TO COTTUS RICEI

Fish (1932) reported the collection of and described larvae and (or) juveniles of what she believed to be Lake Erie representatives of each of the four sculpins recognized as inhabiting the Great Lakes. Unfortuately and as with her descriptions for several other species (Snyder and Douglas 1978, Auer 1982, Fuiman et al. 1983), eight of the twelve cottid specimens she described were misidentified (Table 4, Figures 3 and 4).

Contrary to suspicions by Heufelder (1982), Fish's illustrated descriptions of 12.5 and 16.2 mm specimens attributed to Triglopsis thompsoni (now M. thompsoni), are certainly descriptions of C. ricei and strongly resemble Eastmain River specimens of similar size (Figures 2 and 3).

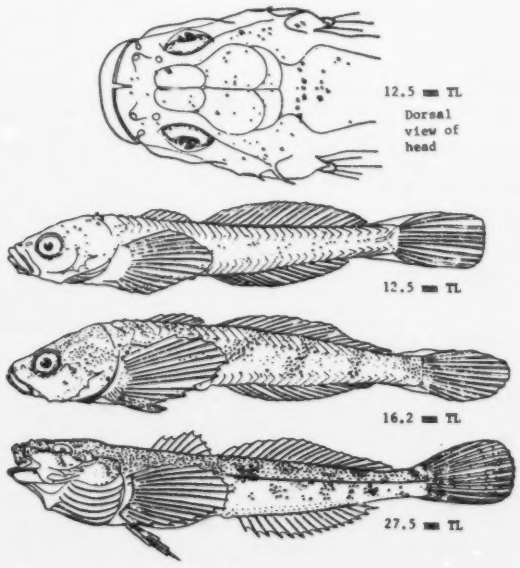

Figure 3. Cottus ricei from Lake Erie. Metalarva (possibly juvenile, 12.5 mm TL) and juveniles (16.2 and 27.5 mm TL) reproduced from Fish (1932). The 12.5 and 16.2 mm specimens were originally described as Triglopsis thompsoni (Myoxocephalus thompsoni).

They differ from similar-sized M. thompsoni larvae described by Khan (1971), Khan and Faber (1974) and Heufelder (1982) in body form, pigmentation, and especially developmental state relative to size (Table 3, Figures 3 and 6). Khan and Faber (1974) themselves mistakenly considered the 16.2 mm description valid for M. thompsoni. Fin and myomere meristics of both specimens fit C. ricei rather than M. thompsoni (Table 2). However, Fish did note that other of the five Lake Erie specimens she assigned to M. thompsoni (all between 12.5 and 16 mm) had pelvic fin counts of I,3 on both sides. The illustrations of Fish's 12.5 and 16.2 mm specimens did not include procurrent caudal rays; we suspect they were overlooked. Fish apparently included only entire myomeres anterior to the posterior margin of the vent in her preanal counts. Most early-life-history biologists now follow Siefert (1969) by including all myomeres transected by a vertical from the vent. If Fish's preanal and postanal counts are adjusted for the difference (on average, a shift of two from postanal to preanal), these counts are nearly the same as those reported by Heufelder (1982) and observed by ourselves.

Fish's 12.5 and 16.2 mm specimens are described as possessing series of prickles (spiny armature) on the body similar to those observed on our specimens. However, the ventral series do not continue beyond the anal fin as in our specimens and while our specimens over 13 mm

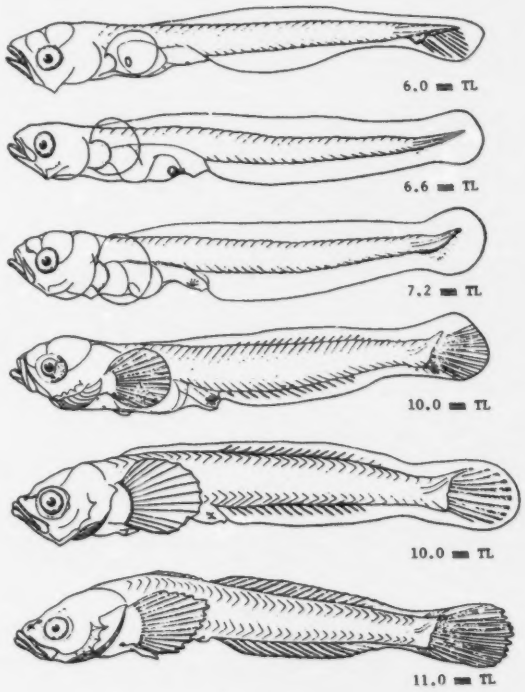

Figure 4. Cottus ricei from Lake Erie. Protolarva (6.6 mm TL), mesolarvae (6.0 and 7.2 mm TL) and metalarvae (10.0, 10.0, and 11.0 mm TL) reproduced from Fish (1932). Although not clearly illustrated as such, the 7.2 mm specimen is assumed to have a few caudal rays and the 10 mm specimens are assumed to have a full complement of 12 principal caudal rays. The 6.0 mm specimen was originally described as Cottus bairdii bairdii and the others, 6.6 through 11.0 mm, were originally described as Cottus bairdii kumlieni. The reassignment of the 6.0 mm specimen to Cottus ricei is tentative.

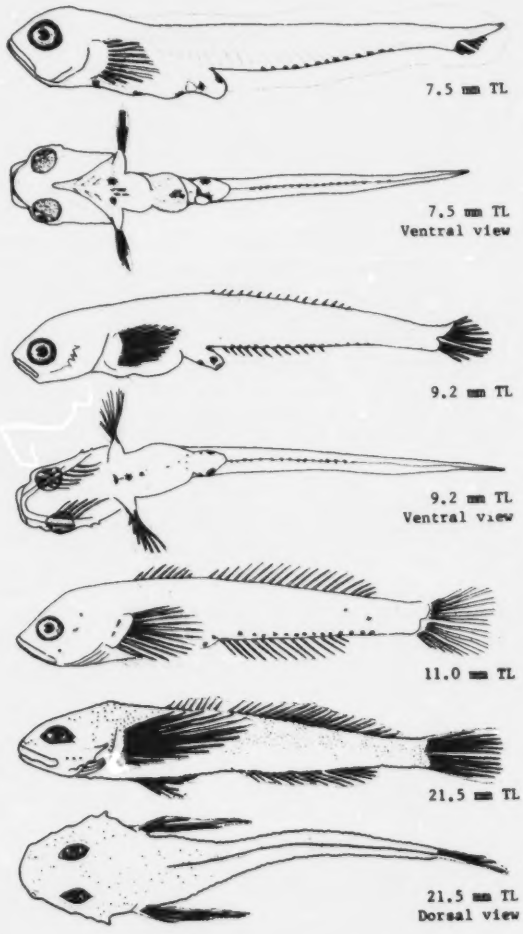

Figure 5. Cottus ricei from Lake Superior. Mesolarva (7.5 mm TL), metalarvae (9.2 and 11 mm TL), and juvenile (21.5 mm) reproduced from Heufelder (1982) with permission from Nancy A. Auer.

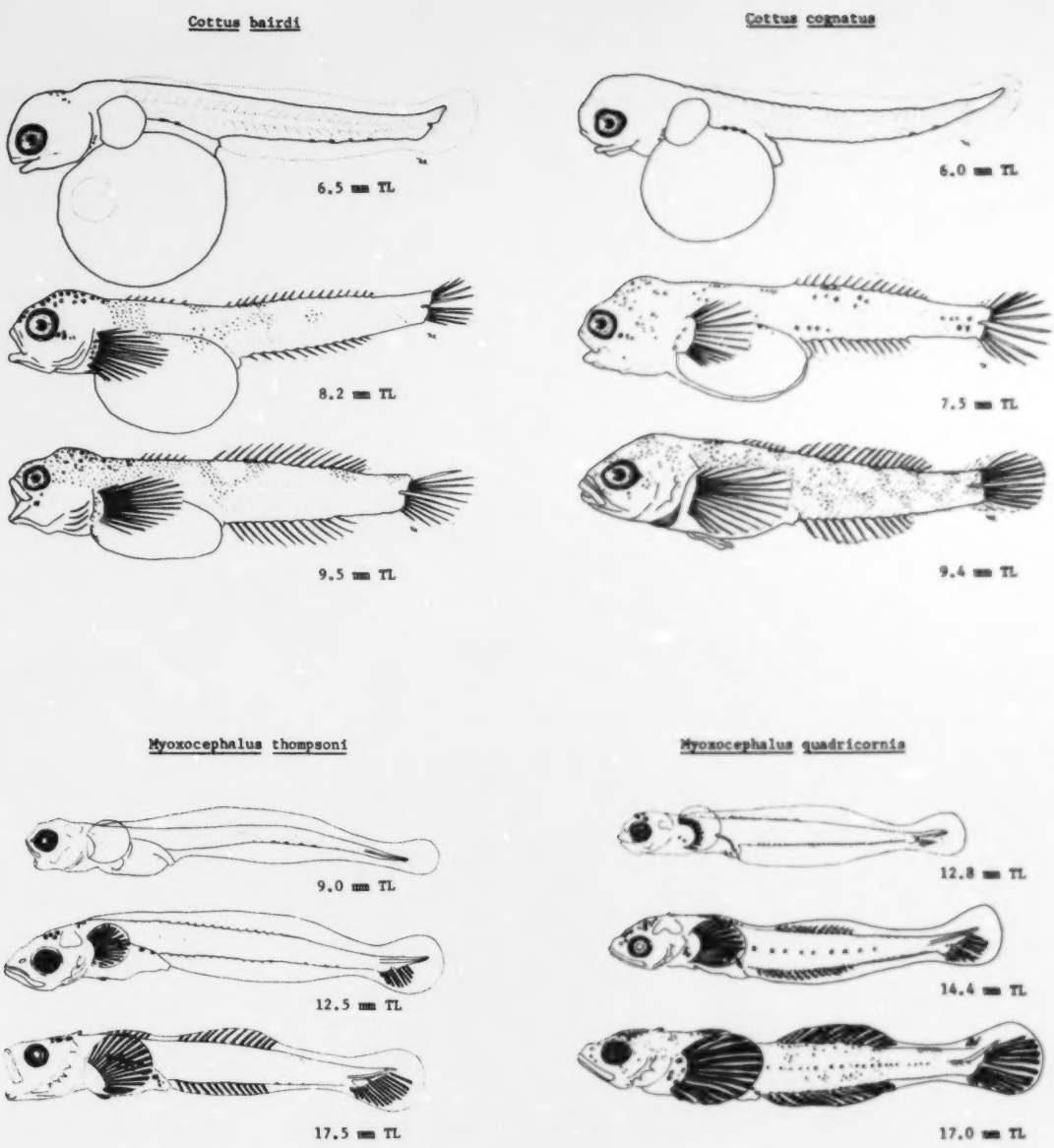

Figure 6. Larvae of Cottus bairdi (6.5 mm TL mesolarva, and 8.2 and 9.5 mm TL metalarvae), Cottus cognatus (6.0 mm TL protolarva; 7.5 mm TL mesolarva, no pelvic fin buds; and 9.4 mm TL metalarva), Myoxocephalus thompsoni (9 mm TL protolarva, 12.5 mm TL mesolarva, and 17.1 mm TL metalarva), and Myoxocephalus quadricornis (12.8 mm mesolarva, and 14.4 and 17.0 mm metalarvae). All specimens were from Lake Michigan except the smallest of the Cottus species which were laboratory reared in Michigan, and the series of M. quadricornis which were from Tuktoyatuk Harbor, Kugmallit Bay, N.W.T. The illustrations were selected from Heufelder (1982 - Cottus species) and Khun and Faber (1974 - Myoxocephalus species) and reproduced with permission from Nancy A. Auer and Daniel J. Faber, respectively.

are covered with prickles over most of the body, her 16.2 mm specimen has only one additional series between the initial dorsal and ventral series. Even her 27.5 mm specimen correctly assigned to C. ricei is described as lacking prickles between the lateral line and a few ventral series along the anal fin. Scott and Crossman (1973) reported prickles only above the lateral line of adult M. thompsoni but none are reported or illustrated for that species through 18 mm by Khan and Faber (1974). C. bairdi and C. cognatus develop prickles only behind the pectoral fins (sometimes extending onto the back in C. bairdi; Scott and Crossman 1973), but even these were not observed or obvious in young C. bairdi from Colorado.

Fish's illustrated descriptions of 6 to 11 mm specimens attributed to C. bairdi were also mistakenly identified. Khan and Faber (1974) ignored their own meristic and developmental state observations on M. thompsoni when they reassigned these descriptions to M. thompsoni (Tables 2 and 3). We confirm Heufelder's (1982) belief that these descriptions represent C. ricei. However, we consider our reassignment of the 6 mm specimen to be tentative. Assuming the size and description reported for the latter specimen is accurate, its size relative to state of development is a bit inconsistent with the other descriptions (Figure 4). It certainly does not represent any of the other cottids known to inhabit the Great Lakes region and based on our current knowledge of fish larvae does not fit in any other family of Great Lakes fishes. These reassigned descriptions correspond reasonably well to C. ricei descriptions by Heufelder and with the smaller C. ricei (10-11 mm) that we examined (Figures 2, 4 and 5). They differ dramatically from C. bairdi and C. cognatus described by Heufelder and Auer (1980) and Heufelder (1982) (Figures 4 and 6). C. ricei bear little or no yolk at sizes for which the other Cottus species possess relatively immense yolk sacs. They hatch at a smaller size but develop fin structure at slightly larger sizes than C. bairdi and C. cognatus. Although the fin meristics for Fish's 10 and 11 mm specimens could apply to either C. bairdi or C. ricei, the adjusted myomere counts for all of Fish's presumed C. bairdi are more appropriate for C. ricei (Table 2).

The information provided by Fish (1932) for an unillustrated 19 mm specimen attributed to C. bairdi is inadequate to positively confirm as C. bairdi. The myomere count of 35 (14 preanal, 21 postanal when adjusted) fits C. ricei, while the fin meristics and morphometrics reported are consistant with both C. bairdi and C. ricei. However, the pigmentation described is probably more applicable to C. bairdi. Also, if the specimen described were indeed C. ricei, it probably would have been characterized by body armature (prickles) and assigned by Fish to either M. thompsoni or C. ricei. Perhaps the myomere count is in error.

Without realizing it, Fish (1932) actually provided a rather comprehensive series of descriptions for C. ricei larvae and juveniles in her section on Cottidae. Only a recently hatched, yolk-bearing specimen is needed to complete the series.

Indeed, the senior author suspects that Fish (1932) also described such a specimen (and the 1.4 to 1.5 mm eggs from which it came) but attributed its identity to Boleosoma nigrum nigrum (now Etheostoma nigrum) in her section on Percidae (page 374, Figure 104). Auer (1982) accepted the description as valid and included the illustration and pertinent data in her own account of E. nigrum larvae. The 5.0 mm specimen is reported to have a myomere count of 33 (13 preanal, adjusted), a snout-to-vent length about 45% of total length (40% in the illustration), an oil globule in the yolk, and no pigmentation except for the eyes. These characters appear consistent with descriptions of the smallest larvae reassigned above to C. ricei, as well as those provided by Heufelder (1982) for C. ricei (Tables 1, 2 and 3, and Figures 4 and 5). In contrast to the 5.0 mm specimen described, E. nigrum have a few more preanal and total myomeres, a snout-to-vent length generally equal to or greater than 50% of total length, a vent located a short distance rather than immediately behind the yolk-sac, and a distinctive pigmentation over the yolk-sac and ventral surface of the body. Like the specimen described, recently hatched E. nigrum possess an obvious oil globule.

However, Dr. Wayne Roberts of the Museum of Zoology, University of Alberta in Edmonton, has reared C. ricei and while he agreed with our reassignment of Fish's 6 through 11 mm C. bairdi, he refuted the above suspected identity of Fish's 5.0 mm E. nigrum. He noted that his recently hatched C. ricei are larger, bear a larger yolk-sac, and exhibit some ventral pigmentation. Accordingly, we await Dr. Roberts' description of recently hatched specimens and consider the description of Fish's 5.0 mm specimen uncertain.

Fish (1932, pages 299 through 305) reported on the collection of 56 cottid larvae and juveniles (6 to 35 mm) in 1928 and 1929 Lake Erie surveys. Based on her identifications and according to her text, these collections provided the first records of M. thompsoni, C. cognatus and C. ricei in Lake Erie. If her descriptions are indeed representative of other specimens designated by her as M. thompsoni and C. bairdi, no M. thompsoni were actually collected and specimens designated as M. thompsoni (12.5 to 16 mm) and C. bairdi, (6 to 12 mm) are actually C. ricei. Distributional or ecological data and conclusions for cottids based on these collections and subsequent work based on the descriptions should be revised accordingly.

DIAGNOSTIC CHARACTERS

At comparable states of development, the larvae of C. ricei vaguely resemble the Myoxocephalus species in form and pigmentation. However, C. ricei, as well as the more distinctly appearing C. bairdi and C. cognatus, are unquestionably distinguished from the larvae of the Myoxocephalus species by the latter's substantially greater size relative to state of development (Table 3). The Cottus species are already metalarvae by the size at which the Myoxocephalus species transform from protolarvae to mesolarvae. They are juveniles by the size at which the Myoxocephalus species acquire their first dorsal fin spines. Myomere counts will also readily segregate most of the Cottus larvae (≤35 total, ≤23 postanal) from Myoxocephalus larvae (≥35 total, ≥24 postanal) (Table 2). There are many additional meristic, morphometric, and pigment differences that at least in combination will segregate the two genera or specifically C. ricei from M. thompsoni or M. quadricornis (Tables 1 and 2, Figures 2 through 6), but in nearly all cases their utilization will be unnecessary for identification purposes.

C. ricei protolarvae, mesolarvae, and even the earlier metalarvae are readily distinguished from those of C. cognatus and C. bairdi by general body form, state of development relative to size, and pigmentation (Tables 3, Figures 2 through 6). C. ricei hatch as protolarvae, probably with moderate-size yolk sacs, and absorb most or all of their yolk by 7 mm when they approach or achieve the mesolarval state. In contrast, C. bairdi and C. cognatus hatch at about 6 or 7 mm as either protolarvae (near transition) or mesolarvae with large yolk sacs, become metalarvae by 7 or 8 mm and complete yolk absorption between 8 and 10 mm. C. ricei become metalarvae at about 9 mm. Pigmentation is sparse and restricted to the ventral surfaces on C. ricei less than 10 or 11 mm. While also sparse and restricted to the ventral surfaces in the earliest larvae of the other Cottus species, pigmentation develops rapidly on the head and body and a juvenile-like pattern is well established by 9 or 10 mm. A juvenile-like pigmentation pattern is not achieved in C. ricei until about 11 to 12 mm. Later mesolarvae, and metalarvae of C. bairdi and C. cognatus typically bear very little or no mid-ventral pigmentation while at least some populations of C. ricei exhibit rather distinctive mid-ventral series or aggregations of melanophores both anterior and posterior to the vent. This mid-ventral pigmentation, as mentioned earlier is also present on C. ricei juveniles from Eastmain River.

The presence of prickles along each side of the bases of the dorsal and anal fins of at least later metalarvae and early juveniles of C. ricei readily and conclusively distinguish these specimens from the later metalarvae and juveniles of C. bairdi and C. cognatus. Prickles on juvenile C. ricei can cover most or all of the lateral surfaces while on the other Cottus species they are restricted generally to patches behind the pectoral fins, if present at all.

Although unnecessary in view of the above, some meristic and morphometric characters are useful diagnostically for separating C. ricei from the other Cottus species, especially when used in combination with each other and previously mentioned characters (Tables 1 and 2). The position and size of the eyes are among the more readily observed morphometric characters for diagnosis of metalarvae and early juveniles. The eyes of C. ricei are typically smaller and the distance between them (interorbital distance) greater than for comparably-sized C. cognatus and C. bairdi. Based on 5 specimens of each species between 13 and 20 mm TL, C. ricei eye diameters and interorbital distances ranged 22 to 25% and 16 to 19% of head length, respectively, while corresponding measures were 27 to 31% and 8 to 18% of head length, respectively, for C. bairdi and 28 to 32% and 10 to 15%, respectively, for C. cognatus. However, variation in these characters is great, especially outside the specified size range, and they should not be used by themselves for separating the species. As in most taxonomic work, use of several characters is preferred to assure accurate identification.

OBSERVATIONS ON COTTUS RICEI SPAWNING SEASONS

The occurrence and size distribution of C. ricei in Eastmain River collections suggests that the fish spawned during mid to late spring in 1980. Heufelder (1982) reported that C. ricei in Lake Superior spawn during mid spring (early May). Assuming that Fish's (1932) descriptions are representative of the cottid larvae she reported in 1928 and 1929 collections, the Lake Erie C. ricei population also spawned predominately in mid to late spring (some spawning continued well into July). These observations are contrary to the late summer and early fall spawning season suspected by Scott and Crossman (1973).

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Larvae of the Manacled Sculpin, Synchirus gilli, F. Cottidae

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INTRODUCTION

Synchirus gilli, the single species in the genus, is a small (maximum 64mm TL) cottid inhabiting shallow coastal waters of the NE Pacific, from southern California to SE Alaska (Hart 1973). Published accounts of ichthyoplankton surveys seem not to include Synchirus larvae, perhaps owing to an extreme nearshore distribution. This paper provides the first description of Synchirus larvae and is based on both reared and wild specimens.

MATERIALS AND METHODS

Recently spawned eggs, pink in colour, were collected from the braids of a rope from 3m below 0-tide on Bowen Island (Howe Sound, B.C. at lat. 49°22'N, long. 123°25'50"W) on January 15, 1984. These eggs hatched on January 31. By diving at the same site on February 28, 1984, 10 egg masses in all stages of development were collected from inside the holdfasts of Laminaria saccharina in the shallow rocky subtidal region. These masses hatched between February 28 and March 30, 1984.

Larvae from these hatches were reared in the laboratory in a 1000 l tank with through-flowing seawater of 9-10°C and 27 ppt salinity. Yolk-sac larvae were fed newly hatched Balanus nauplii, the diet for older larvae being supplemented daily with freshly hatched Artemia nauplii. Samples of four or more larvae were preserved at weekly intervals or more frequently. Settlement occurred two months after hatching.

In March, April and May of 1984, plankton tows were taken at three sites along the steep, rocky shoreline of Popham Island, Howe Sound, B.C. (lat.49°21'40"N, long. 123°29'W). Oblique tows with a net of 500 micron mesh were conducted at distances of 0, 4, 20 and 500m from the shore at each site, the 0m tows being guided by divers. Samples were fixed in 1-3% formalin in seawater at capture, then later transferred to 3% formalin.

Larvae were examined under a dissection microscope and drawings were made with camera lucida. Dorsal, anal and pectoral fin ray counts were recorded in addition to the myotome counts, branchiostegal ray counts and the number of preopercular spines. Some Synchirus from all stages of development were cleared and stained following the procedure outlined by Potthoff (1984). The procedure did result in a majority of specimens being overstained with alcian blue, making it difficult to take some counts. Several samples were therefore stained using a modification of the above technique. Specimens were fixed, dehydrated and raised to a neutral pH as detailed by Potthoff, but in half the time, and the cartilage staining step was omitted. The specimens were digested in trypsin for two hours and placed in a modified alizarin red/KOH solution. Using an alizarin solution at 10% of the strength recommended by Dingerkus and Uhler (1977), the larvae were then put through the usual KOH:glycerin series before being preserved in 100% glycerin with thymol.

Data were analyzed separately for wild versus reared larvae. It should be noted that reared larvae were directly killed in 3% formalin whereas some wild larvae died during capture, so that additional shrinkage may have occurred prior to fixation.

NATURAL HISTORY

Synchirus gilli larvae were found only in samples from 0 and 4m from the shore. It is of note that, during May, S. gilli were found in all stages of larval development, from hatching to settlement, which indicates a spawning period from January to April. Hart (1973) reported ripe females in early May. Egg masses contain about 15-30 eggs. Ovaries have several modes of developing ova, so females probably spawn repeatedly during winter/spring.

Kendall, A.W., Jr. and J.B. Marliave (editors). 1985. Descriptions of early life history stages of selected fishes: from the 3rd International Symposium on the Early Life History of Fishes and 8th Annual Larval Fish Conference, May 1984, University of British Columbia, Vancouver, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 1359: 82 p.

IDENTIFICATION

Synchirus gilli larvae have a slender body, short gut and relatively little pigment (Figure 1). Preflexion larvae have melanin only on the gut and ventral midline, and the posterior portion of the dorsal gut melanophore patch usually forms distinctive bars. Head spines are absent aside from the four principal preopercular spines, which develop varying numbers of accessory or inner shelf spines in preflexion larvae. Among cottids, *Synchirus* has unusually high numbers of postanal ventral midline melanophores (avg. 50 ± 7 std. dev.). The pectoral fins grow toward each other ventrally during larval development, producing the appearance on which the common name "manacled sculpin" is based.

Based on preopercular spine counts (avg. 4-9) *Synchirus* larvae might be confused with species in the *Artedius-Clinocottus-Oligocottus* group (Richardson and Washington 1980). *Synchirus* larvae, however, lack such diagnostic features as dorsal gut diverticulae, trailing hindgut, nape bubble, parietal spines, nape melanophores, finfold melanophores or lateral trunk melanin. *Synchirus* larvae occur together with *Oligocottus maculosus* larvae, however, and some aberrant *O. maculosus* individuals have appeared similar to *Synchirus*. These individuals lacked the nape bubble typical of *O. maculosus* and had discrete dorsal gut melanophores which almost formed bars posteriorly.

Larvae of *Synchirus gilli* are almost unmistakable compared with described cottid larvae, except possibly small *Artedius harringtoni* or *Leptocottus armatus*. Larvae of *A. harringtoni* can be separated on the basis of their dense nape melanin and diffused rather than discrete melanophores over the dorsal gut. Both *S. gilli* and *L. armatus* have melanic bars over the dorsal gut, but they only occur over the posterior gut in *S. gilli*, whereas the entire gut has this appearance of "honeybee banding" in *L. armatus*. *Leptocottus armatus* larvae furthermore possess a distinctive, internal horizontal band of melanin between the eyes, from the snout to the dorsal insertion of the pectoral fin (Richardson and Washington 1980).

On the basis of median fin and vertebral meristics (usually dorsals X,20; anal 20; vertebrae 38) *Synchirus* larvae overlap in their counts with *Radulinus* spp. *Radulinus* spp., however, possess dense lateral trunk melanin and their snout-anus length is about .5 SL throughout larval development (Richardson and Washington 1980). *Synchirus* larvae have snouth-anus lengths which increase from .37 to .42 SL with development and they have slightly more pectoral rays (usually 21) than *Radulinus* spp. (up to 20, Hart 1973).

PIGMENTATION

As mentioned above, the "honeybee banding" (bars) of melanin over the posterior gut of *Synchirus* larvae is an obvious diagnostic feature of most preflexion larvae. All dorsal gut melanophores are discrete in this species. The absence of these bars in some larvae may simply result from contraction of those melanophores, since the bars fade or bleach with preservation and staining more rapidly than the more anterior melanophores, suggesting greater diffusion (expansion) of melanic pigment in the bars. These bars become obscure during flexion and the entire dorsal patch of melanophores recedes toward the dorsal midline of the gut.

Throughout larval development there is a pair of rows of ventral midline gut melanophores. Sometimes the midline row is single, splitting into a ring encircling the anus and sometimes the double rows join into a single line at the two ends of the gut. These lines can either consist of discrete melanophores or fused lines of melanin. During flexion, the ventral gut develops a pair of prominent melanophores anterior to the insertions of the pelvic fins. These melanophores migrate posteriorly with the pelvics during postflexion, as will be discussed. A large internal melanophore usually marks the anterior end of the gut, the melanophore developing after yolk resorption.

Head melanin develops during flexion, as a central patch of cranial melanophores which later extend posteriorly, becoming internal along the brainstem case. In postflexion larvae these melanophores extend progressively further posterior along the dorsal surface of the notochord (internal, not illustrated). Postflexion larvae also develop melanophores along the base of the first dorsal fin and a few melanophores may appear below the jaw or on the tip of the snout and maxilllary. Overall, *Synchirus* larvae remain relatively unpigmented until they have settled, when a uniform scattering of fine melanophores develops over the entire body, along with extensive development of orange-brown erythrophore pigmentation.

Perhaps the most certain diagnostic feature in pigmentation is the consistently high count of postanal ventral midline (PVM) melanophores (Tables 1 and 2). The PVM counts for preflexion and flexion larvae ($\bar{x}$ = 51 and 47, respectively) exceed those for all the cottid species reported by Richardson and Washington (1980). The more anterior PVM melanophores, which correspond to anal fin rays in postflexion larvae, are larger and more widely spaced than posterior PVM melanophores. The finer PVM melanophores toward the caudal fin decrease in number in postflexion larvae, average counts decreasing to 31-34. Developmental reductions in

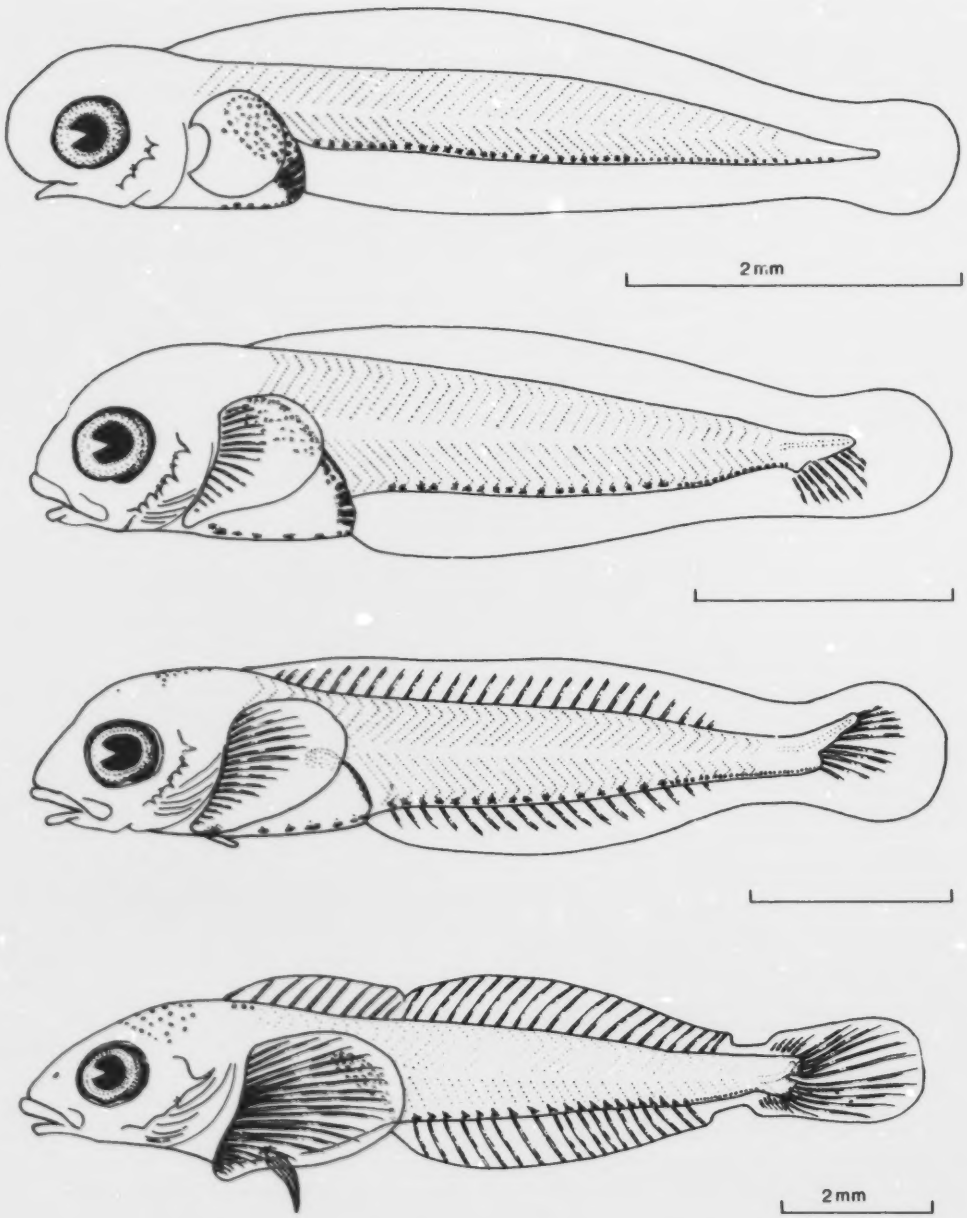

Figure 1. Larval stages of Synchirus gilli. Lengths from top to bottom: 5.2mm NL, 6.4mm NL, 8.3mm NL, 9.8mm SL.

numbers of PVM melanophores in cottid larvae have been documented by Richardson and Washington (1980) and Marliave and Elderton (1982).

MORPHOLOGY

The body shape of Synchirus larvae is most similar to the Group 2 genera (Paricelinus, Triglops, Icelus, Chitonotus, Icelinus) of Richardson (1981), in terms of the slender body and pointed snouth. Body depth actually increases rapidly in preflexion larvae from about .18 to .24 SL (at pectoral base), but it then decreases to about .20 SL during flexion and remains slender through settlement. Head length is about .23 SL from hatching through flexion, then increases to .28 SL in postflexion larvae nearing settlement (12-16mm SL). The snout-anus length increases progressively from .37 SL at hatching to .46 SL near settlement (Tables 1, 2). The snout becomes increasingly pointed until postflexion larvae come to closely resemble adults in morphometry.

Aside from body proportions and snout shape, the size and conformation of the pectoral fins in postflexion larvae are characteristic of adult Synchirus. Through larval development, the pectoral fins grow antero-ventrally at their ventral insertion. In postflexion larvae of 10mm SL (as illustrated) the pectoral fin bases are contiguous ventrally, but not joined as in adults. At sizes between 12 and 14mm SL, depending on the individual, the pectoral fins become united ventrally, the membrane and ventralmost rays lengthening to the extent that union of the pectoral fins is unmistakable in larvae of 16mm SL.

Pectoral and caudal fin rays develop first in preflexion larvae. Dorsal and anal rays develop simultaneously during flexion, at which stage the pelvic fin buds emerge below the posterior margin of the operculum, near the ventral insertion of the pectoral fins. During postflexion, the pelvic fins migrate posteriorly as their rays develop, reaching their adult position in larvae of 10mm SL. Even in larvae of 16mm SL, however, the anus remains near the origin of the anal fin. Hart (1973) reports the adult to have the anus far forward, closer to the pelvic fins than to the anal fin. The anus was midway between these fins in a juvenile of 24mm SL.

Table 1. Average measures and meristics of 159 reared Synchirus gilli larvae (± Std.Dev.). PVM = postanal ventral midline melanophores. Note that SL is NL for preflexion larvae.

Stage	Yolk-sac	Flexion	Postflexion	Postflexion
No. Hatches	3	6	6	6
Sample Size	n=103	n=35	n=16	n=5
Avg. SL (mm) ± S.D.	4.26 ± 0.25	6.46 ± 1.24	9.6 ± 0.99	12.4 ± 0.4
Snout-Anus into SL	37%	39%	41%	42%
PVM Count	51 + 7	47 ± 11	31 ± 7	34 ± 3
1st Dorsal Count	-	(27.5 ± 0.7)	10 ± 0.5	9.5 ± 0.6
2nd Dorsal Count	-		19.9 ± 1.6	20 ± 2
Anal Fin Count	-	-	19.4 ± 0.9	19 ± 0.8
Pectoral Count	-	15 ± 2	20.3 ± 0.8	20.5 ± 1
Preanal Myotomes	-	9.4 ± 1.4	9.3 ± 0.5	9
Postanal Myotomes	-	27.5 ± 1.8	27.3 ± 0.8	26.5 ± 0.7
Branchiostegal Ray Count	-	3.6 ± 1.3	5 ± 0.4	5
Preopercular Spine Count	-	7.4 ± 1.4	4.4 ± 2.3	4.3 ± 4.9

Table 2. Average measures and meristics of 165 wild-captured Synchirus gilli larvae (± Std.Dev.). PVM = postanal ventral midline melanophores. Note that SL is NL for preflexion larvae.

Stage	Preflexion	Preflexion	Flexion	Postflexion	Postflexion	Postflexion
Sample Size	n=13	n=21	n=48	n=33	n=38	n=12
Avg.SL (mm) ± S.D.	4.13 ± 0.23	5.18 ± 0.36	7.00 ± 0.72	9.67 ± 0.82	12.02 ± 0.97	16.25 ± 3.36
Snout-Anus into SL	38%	38%	38%	44%	42%	46%
PVM Count	47.46 ± 3.48	47.00 ± 5.92	44.61 ± 7.20	30.57 ± 6.41	32.49 ± 3.94	33.79 ± 5.83
1st Dorsal Count	-	-	-	9.63 ± 0.75	9.97 ± 0.30	9.93 ± 0.27
2nd Dorsal Count	-	-	-	20 ± 0.88	20.14 ± 0.59	20.14 ± 0.53
Anal Fin Count	-	-	-	19.33 ± 1.01	20.81 ± 1.21	19.85 ± 0.55
Pectoral Count	-	-	-	21.4 ± 1.54	21.38 ± 1.26	20.79 ± 1.05
Preanal Myotomes	-	-	9.13 ± 1.25	9.97 ± 0.43	10.28 ± 0.51	10.5 ± 0.52
Postanal Myotomes	-	-	27.18 ± 1.01	27.5 ± 1.19	27.78 ± 0.76	27.53 ± 0.64
Branchiostegal Ray Count	-	-	4.75 ± 0.93	5.6 ± 0.67	5.58 ± 0.84	5.57 ± 0.51
Preopercular Spine Count	-	-	9.00 ± 1.55	9.03 ± 2.67	3.61 ± 1.50	2.85 ± 1.07

SPINATION

Synchirus larvae possess strong preopercular spines at hatching, but otherwise lack spines during early larval development. Postflexion larvae have ossified nasal bones, but the nasal spines are not evident until larvae reach 12mm SL, at which stage all but the uppermost preopercular spine have become reduced. By 14mm SL, the nasal spines are pronounced and the single preopercular spine has become bifid, as in the adult.

Newly hatched Synchirus have four equal preopercular spines, as do Richardson's (1981) Group 2 cottid larvae, but Synchirus also have two or three inner shelf (accessory) preopercular spines. During preflexion development, these accessory preopercular spines increase in number and more spines grow from the posterior margin of the preopercle, so that by flexion there may be as many as nine pronounced spines. The lower spines rapidly become blunt and the accessory spines disappear as the upper spine curves upward (by 11-12mm SL). The upper spine becomes bifid, as in the adult, with the growth of a spur on either the dorsal or ventral edge at 13-14mm SL. Lateral line scales develop as apparent spines in juveniles over 20mm SL.

MERISTICS

Meristic data for reared versus wild specimens in Tables 1 and 2 vary only slightly and probably reflect only the interpretations of two different technicians. Another confounding influence was whether or not specimens had been cleared and stained. The myotome counts match the adult vertebral count of 38-39 (Richardson and Washington 1980) fairly closely, but tend to be one short, possibly because the urostylar segment was not counted. The first dorsal counts were almost always 9 or 10 and the second dorsal and anal 20 and 19, respectively. The meristic range for the present material is narrower than the data compilation in Richardson and Washington (1980), agreeing more closely with Hart (1973). Branchiostegal counts were usually four at flexion and 5-6 in postflexion larvae, but a close examination of alizarin-stained postflexion specimens revealed a fine 7th branchiostegal in some. This observation contrasts with the constant count of six for adults listed by Richardson and Washington (1980). Counterstained specimens usually retained too much alcian blue, so the clearest counts were from material only stained for bone.

OSTEOLOGY

At the earliest stages of preflexion (approximately 4.1mm NL), only the cleithrum is ossified. Next, the lower jaw starts to ossify and there are indications of ossification in the branchiostegals and in the preopercular spines (5.5mm NL - preflexion). At standard lengths of 7.0-7.5mm (preflexion/flexion), the branchiostegals and preopercular spines are fully ossified as intermembranous bone and the premaxillary and maxillary are ossifying. There is bone formation along the posterior edge of the operculum. By the onset of flexion (7.5mm SL), the jaws are an entirely alcian-stained element and the branchiostegals are nearly fully ossified. The ossification of caudal and pectoral rays is completed during flexion. There is no alizarin stain uptake at flexion in the rays of the dorsal and anal fins.

At standard lengths approaching 9.0mm (flexion), the upper and lower jaws and the opercular bones including the branchiostegals are fully ossified. Bone formation is starting in the cranium along the dorsal edges of the orbits. The anterior vertebrae have ossified and ossification is proceeding posteriorly. The first anterior five neural arches have started to ossify. In the caudal rays, intermembranous bone formation has initiated at the base of each ray and moves posteriorly towards the distal end of the rays. Ossification of the rays in the pectoral fins also starts at the fin base moving towards the extremeties and by this stage, up to two thirds of the ray length is ossified. During flexion, fin ray formation starts simultaneously in both the dorsal and anal fins at the point of their origin and ossification moves posteriorly. Some specimens appear to have the first dorsal developing elements at a slower rate than that of the second dorsal and anal fins.

In specimens slightly larger than 9.0mm SL (9.1-9.2mm SL), the caudal complex is starting to ossify. The urostyle is becoming bone but the hypural plates are still cartilaginous. Examining the pattern of development in the caudal rays, one sees alizarin uptake starting with the median rays and proceeding both dorsally and ventrally while at the same time moving towards the ray tips. The principal caudal ray count is 6+5 with five dorsal secondary rays and six ventral secondary rays. There are six obvious teeth along the upper jaw and four in the lower jaw.

By the end of flexion (9.8-10.0mm SL), the jaw and opercular bones are ossified while the cranium is only partially ossified. Ossification in the cranium, as indicated by alcian blue uptake, appears to begin at the periphery of each bone and moves towards the centre. By this stage, approximately three quarters of the vertebrae including the neural and haemal arches are alizarin-stained bone. The principal caudal rays are nearly complete bone and the hypural plates are slightly alizarin stained, indicating the onset of bone formation. In the pectorals, only the tips of the rays are not ossified. All fin rays in both dorsal fins and anal fins are present as dermal bone. At the completion of the fin ray formation stage, one can see ten maxillary and eight mandibular teeth in the jaws.

By the time the preopercular spine becomes bifid at 13.0-14.0mm SL, the development of the cranium, vertebrae and fin elements is complete. Specimens in this size range have 12 abdominal and 26 caudal vertebrae and there are 12 teeth along the edge of the upper jaw and 10 mandibular teeth. The caudal formula is 6+5 with 8-9 dorsal secondary rays and 7-8 ventral secondary rays.

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LARVAE AND JUVENILES OF AURORA ROCKFISH, *Sebastes aurora*, FROM OFF CALIFORNIA AND BAJA CALIFORNIA

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INTRODUCTION

Adults of Sebastes aurora are uniformly pink-red in coloration, moderate in size (up to 40 cm) and have been reported from Amphridite Pt., Vancouver Island, to San Diego, California, in depths of 180-768 m (Miller and Lea 1972; Eschmeyer et al. 1983). They are a minor component of trawl catches from deep soft-bottom habitats (W.H. Lenarz, NMFS, Tiburon Lab., pers. comm.). Published fishery and life history information of this species is lacking.

Sebastes aurora is the eighth eastern Pacific Sebastes species for which complete life history stages are known. Others are S. cortezi, S. dallii, S. jordani, S. levis, S. macdonaldi, S. melanostomus and S. paucispinis (Moser et al. 1977; Moser and Ahlstrom 1978; Moser and Butler 1981). Five other species have been reared to the stage of notochord flexion--S. rufus and S. constellatus (Moser and Butler, In press); S. caurinus and S. auriculatus (Stahl-Johnson, this volume); S. melanops (G.W. Boehlert, NMFS, Honolulu Lab., pers. comm.). Postflexion stages have been described for seven species--S. crameri, S. helvomaculatus and S. pinniger (Richardson and Laroche 1979); S. flavidus and S. melanops (Laroche and Richardson 1980); S. entomelas and S. zacentrus (Laroche and Richardson 1981). Information on pre-extrusion, newborn or first-feeding larvae is available for 28 other species (Moser et al. 1977; Kendall 1982; Washington et al. 1984), leaving 22 eastern North Pacific species for which life history stages have not been described. The use of ichthyoplankton surveys in estimating spawning biomass and recruitment of Sebastes species is impaired by the large species complement and the inadequate knowledge of their early life histories. This paper employs specimens from ichthyoplankton and trawl collections anc the technique of tracing larval series backward from identifiable juveniles. The companion paper (Stahl-Johnson, this volume) describes larval stages of two nearshore species reared from larvae extruded from identified females. Extensive use of these techniques is necessary to fill in the gaps in our knowledge of Sebastes life histories.

MATERIALS AND METHODS

Material for early life history description was based on the 415 larvae and early pelagic juvenile specimens (3.0-21.5 mm in length) collected on California Cooperative Oceanic Fisheries Investigations (CalCOFI) plankton surveys from 1949 to 1981. Eleven pelagic juveniles (14.4-34.4 mm SL) were obtained from midwater trawl collections of the Natural History Museum of Los Angeles County (LACM Cat. Nos. 9369-17, 9674-16, 9677-11, 9943-17, 30202-7, 30203-3, 30270-9, 30526-13, 36303-1, and 36313-1). Two benthic juveniles (38.3 and 38.9 mm SL) were obtained from bottom trawl samples of Scripps Institution of Oceanography (SIO Cat. Nos. 70-350 and 84-47). Descriptive methods and terminology follow Moser et al. (1977) and Moser and Ahlstrom (1978).

Fresh specimens for aging were obtained from the stomach contents of albacore (Thunnus alalunga) taken in August 1977 about 129 km south-southwest of San Diego, California. The otoliths were prepared and analyzed according to the methods of Brothers et al. (1976).

DESCRIPTION OF DEVELOPMENT

GENERAL DEVELOPMENT

Larvae of S. aurora are released principally during the winter and spring and are about 4.0 mm long at birth (Fig. 1). Notochord flexion occurs in a size interval of about 6.5-8.6 mm and transformation to the pelagic juvenile stage occurs at about 13 mm SL (Table 1). Our largest pelagic juvenile was 34.4 mm SL; the smallest benthic juvenile was 38.3 mm SL (Fig. 2).

MORPHOLOGY

Larvae have a distinctive shape; the head and mouth are large and the produced snout has a concave dorsal profile. The snout-anus distance is relatively greater than in other species studied (Table 2). Pelagic juveniles have a relatively large head and mouth; however, the dorsal snout profile is slightly convex.

Sebastes aurora develops a nearly complete complement of head spines; the sequence of their appearance is listed in Table 3. The parietal spines are relatively small, weakly serrated and lie flat against the head. The 2nd and 3rd anterior preopercular spines, and the 1st and 4th upper infraorbitals are lost during the pelagic juvenile stage; the pterotic, lower posttemporal and cleithral spines are lost in the benthic juvenile stage.

FIN DEVELOPMENT/MERISTICS

The principal caudal fin rays are the first rays to begin ossification, at about 5.3 mm. The full complement of 8 + 7 rays is present at 8.0 mm at which size the procurrent caudal rays begin ossifying (Table 4). Ossification of the pectoral fin rays begins at about 5.6 mm and the full complement is ossifying at about 8.3 mm. The pectoral fin attains a moderate size compared with that in other Sebastes species (Table 2). Ossifying dorsal and anal fin rays are present during notochord flexion and the full complements are present in early postflexion larvae. The gill rakers on the lower limb of each arch appear at about 5.6 mm and the full complement on both limbs (24-28) is ossifying at the end of the larval period. Only one other species of eastern Pacific Sebastes, S. rastrelliger, has a lower count. The

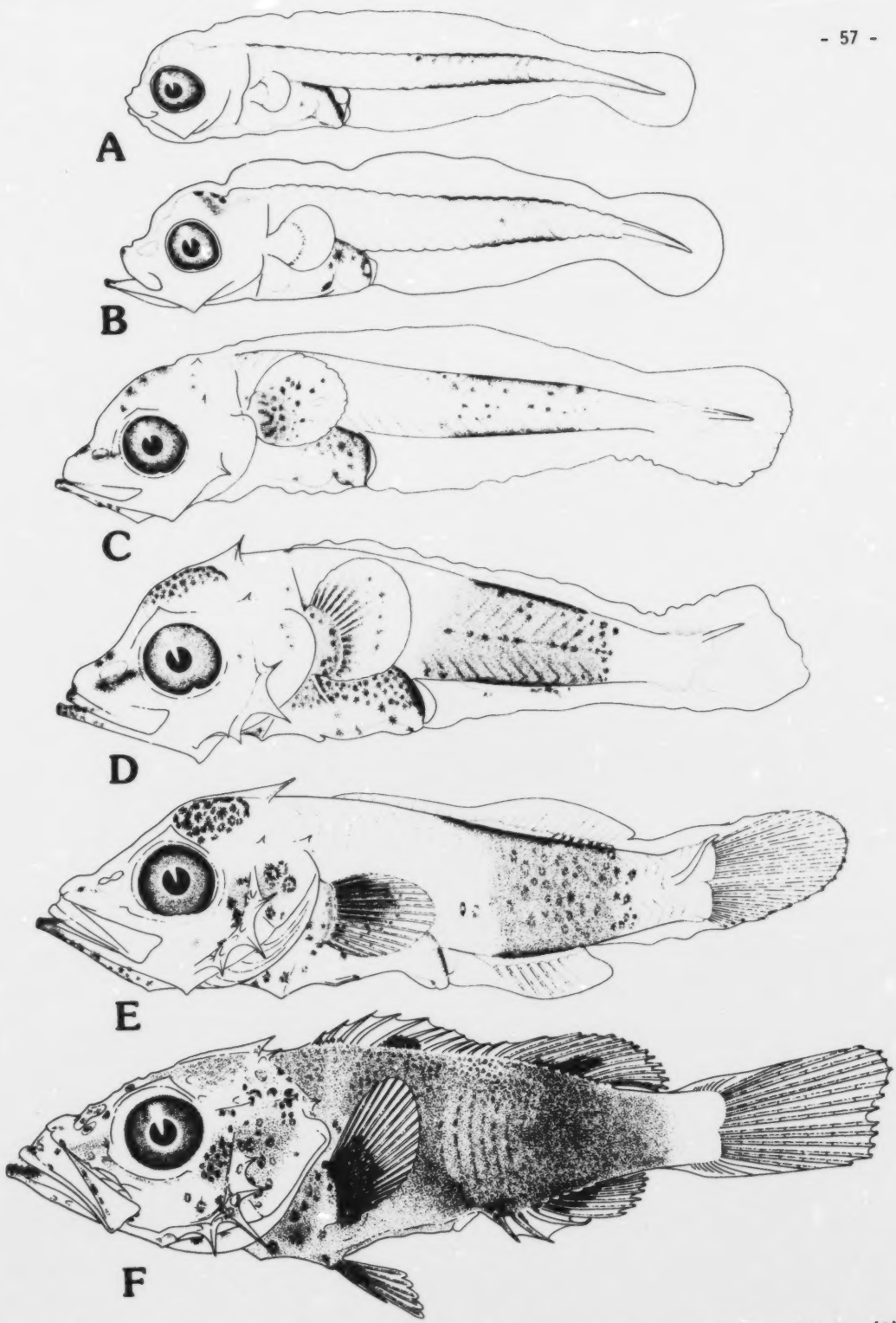

Figure 1. Developmental series of S. aurora. (A) 4.4 mm larva, Scripps 2-6-B, Sta. 3-1-A; (B) 4.8 mm larva, CalCOFI 4908 (H6) 802; (C) 6.5 mm larva, Scripps 2-6-B, Sta. 3-1-A; (D) 6.7 mm larva, CalCOFI 5005 Sta. 130.40; (E) 8.3 mm larva, CalCOFI 7507 Sta. 90.70; (F) 13.5 mm pelagic juvenile, LACM 30270-9.

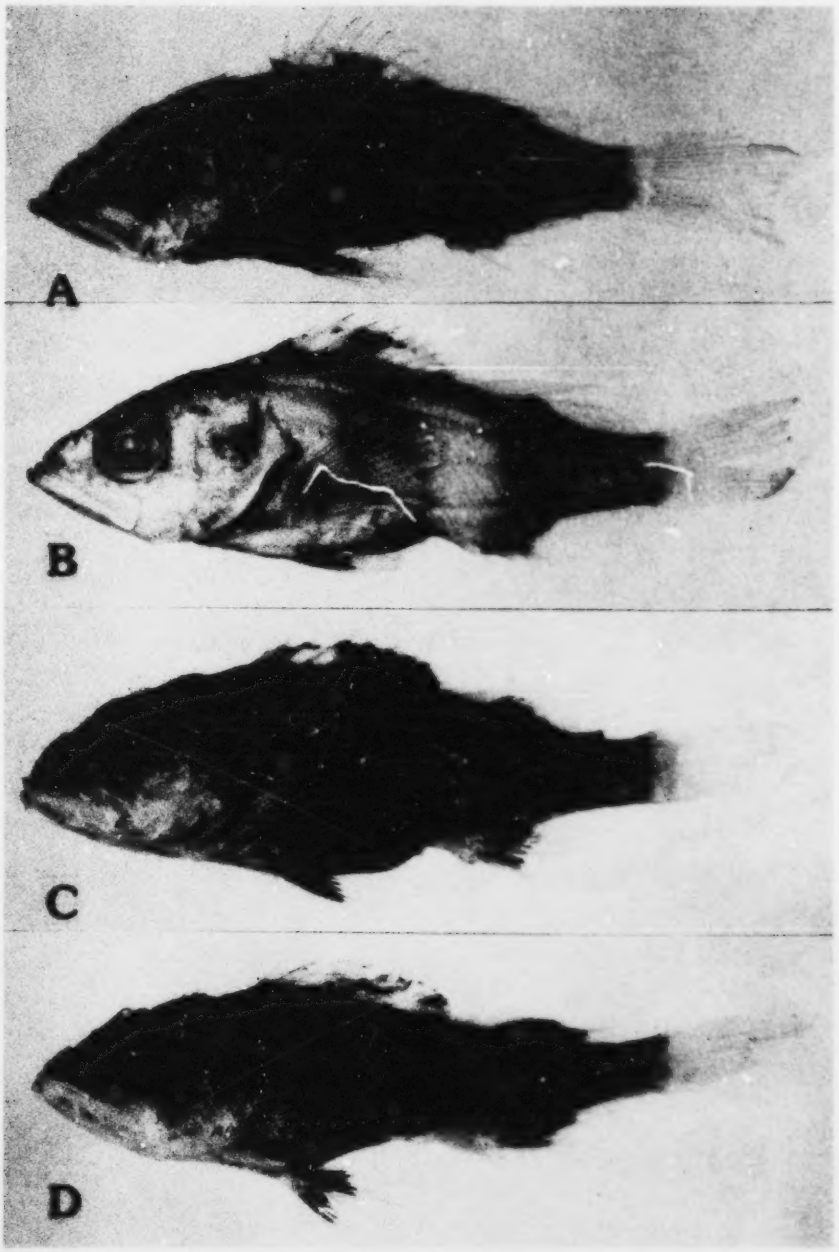

Figure 2. Developmental series of S. aurora. (A) 18.6 mm pelagic juvenile, LACM 30202-7; (B) 28.3 mm pelagic juvenile, LACM 36313-1; (C) 34.4 mm pelagic juvenile, LACM 36303-1; (D) 38.9 mm benthic juvenile, SIO 70-350.

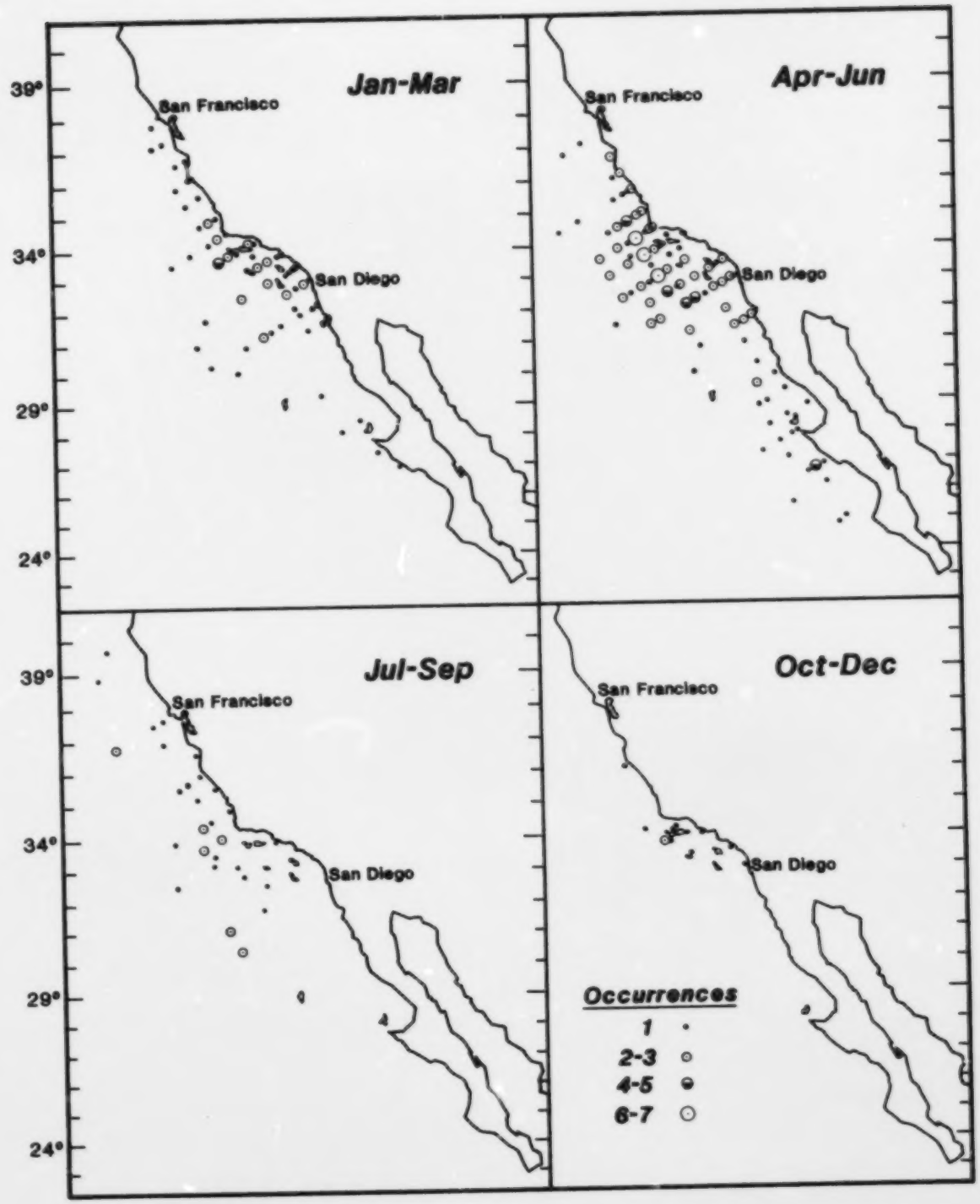

Figure 3. Numbers of occurrences of larvae of S. aurora in standard CalCOFI tows taken during 1959-1981 and pooled by season.

full complement of 27-30 lateral line scales, the lowest count among eastern Pacific Sebastes, is present about mid-way through the pelagic juvenile stage. The combination of these two counts is diagnostic for the species.

PIGMENTATION

Larvae of S. aurora have an unusual pigment pattern. Newborn larvae have a melanistic sheath above the gut and a distinctive band extending from the 4th or 5th postanal myomere to the 14th or 15th. Most of the melanophores are concentrated near the dorsal and ventral midlines but some occur laterally and many are deeply embedded in the myomeres (Fig. 1). Melanophores can be counted in only a few specimens in which the pigment cells are contracted. A 3.8 mm larva had about 45 melanophores above the horizontal septum and 35 below. In four specimens between 4.5 mm and 6.1 mm the counts range from about 63-100 above the septum and 44-73 below. The band enlarges and becomes more prominent in later larval stages and appears as a dusky bar in pelagic and benthic juveniles (Fig. 2). The head becomes heavily pigmented in preflexion larvae as pigment develops above the brain, on the nape, upper jaw, lower jaw, gular region, isthmus, otic region, cleithral region and snout. The deeply embedded pigment in the snout is a diagnostic feature. During the preflexion stage, groups of melanophores appear posterior to the eye on the preopercle and opercle. The pectoral fin becomes heavily pigmented during the preflexion period; the fin base develops solid pigmentation on both medial and lateral surfaces and the blade is pigmented except in the distal region. During notochord flexion pigment begins to develop on the proximal regions of the pelvic fins and the anal fin. Transition to the pelagic juvenile stage involves an expansion of the tail bar posteriorly and anteriorly and the appearance of pigment over the entire head and body. A second dusky bar appears at midbody below the 5th-11th spinous dorsal rays and a small pigment saddle forms below the 1st-3rd spinous rays. Three blotches form on the membrane of the spinous dorsal at rays 1-3, 5-7, and 9-11. A large blotch develops on the proximal region of the soft dorsal. In large pelagic juveniles the distal margin of the spinous dorsal fin develops a series of black markings.

DISTRIBUTION AND GROWTH

Adults of S. aurora have been reported from central Baja California to southern British Columbia. Distribution of the larvae collected on CalCOFI surveys indicates that the southern limits of the distribution are south of Punta Eugenia, Baja California (Fig. 3). Larvae of S. aurora occurred in 292 of 14,124 CalCOFI samples taken at 136 stations from 1949 to 1981 in a region extending from Cape Mendocino, California, to off Thetis Bank, Baja California. Seasonal fluctuations in abundance were evident with occurrences most numerous in April-June (166 occurrences in 4762 tows, 3.5%) followed by January-March (79 occurrences in 4083 tows, 1.9%), July-September (36 occurrences in 2928 tows, 1.2%), and October-December (11 occurrences in 2351 tows, 0.5%). Individuals ranged in size from 2.8-21.5 mm; 92% were 8.5 mm or less. Larval size was independent of season and distance offshore.

Examination of the otoliths of specimens taken from albacore stomachs showed an estimated age of 68 days for a 17.6 mm SL pelagic juvenile, 76 days for one 25.3 mm SL and 80 days for one 26.8 mm SL (Fig. 4). This is similar to age estimations for pelagic juveniles of S. melanostomus, a species with a similar early life history (Moser and Ahlstrom 1978). Adults of both species occupy deep slope habitats and have distinctively banded pelagic juveniles which attain a length of 35-40 mm SL and an age of 3-4 months before settling. The pigment pattern of strong dark bands alternating with almost transparent body regions is also found in pelagic juveniles of the subgenus Sebastomus and the genus Sebastolobus and may function to conceal the juveniles during their extended midwater life (Moser and Ahlstrom 1978).

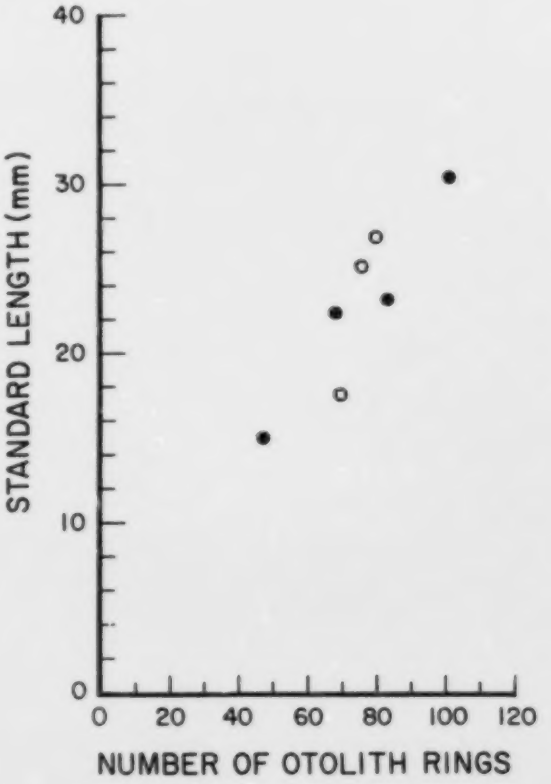

Figure 4. Estimated ages of pelagic juveniles of S. aurora and S. melanostomus based on counts of daily growth rings of sagittae.

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Barbara Sumida MacCall, Elizabeth Stevens and Morgan Busby helped identify and measure larvae of S. aurora from the CalCOFI collections. Henry Orr illustrated the larvae. Typing services were provided by Mary DeWitt. Pelagic juveniles were obtained from trawl samples provided by Dr. R. J. Lavenberg (Natural History Museum of Los Angeles County); Dr. R. H. Rosenblatt and W. Wakefield (Scripps Institution of Oceanography) loaned demersal juveniles. Susan Longinotti prepared and aged the otoliths. Rich Charter and Larry Zins helped with the CalCOFI data base.

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Table 1. Measurements (mm) of larvae and juveniles of Sebastes aurora. Specimens between dashed lines are in the notochord flexion stage and specimens between solid lines are pelagic juveniles.

Station	Body length	Snout-anus length	Head length	Snout length	Eye diameter	Body depth	Pectoral fin length	Pectoral fin base depth	Pelvic fin length	Snout-anal fin distance
5404 117.37.5	3.8	1.5	0.80	0.22	0.31	0.64	0.25	0.22		
5206 90.33	4.0	1.5	0.84	0.22	0.30	0.60	0.21	0.24		
5305 77.60	4.2	1.7	0.94	0.22	0.32	0.73	0.24	0.26		
Scripps 36B-31A	4.4	1.8	1.0	0.24	0.38	0.76	0.28	0.27		
7805 87.60	4.6	2.0	1.2	0.34	0.43	0.88	0.34	0.34		
4908 802	4.8	2.1	1.2	0.40	0.41	0.94	0.38	0.34		
6504 83.51Reg	5.0	2.1	1.2	0.34	0.40	0.90	0.35	0.32		
5104 130.3 .34	5.2	2.2	1.4	0.44	0.49	1.2	0.43	0.36		
7203 100.80	5.5	2.4	1.6	0.45	0.49	1.1	0.46	0.40		
8104 83.3 .42	5.7	2.7	1.5	0.45	0.46	1.1	0.47	0.40		
7807 77.60	5.9	2.8	1.8	0.58	0.58	1.3	0.58	0.56		
5404 127.37	6.1	2.9	1.8	0.66	0.53	1.4	0.54	0.50	0.02	3.3
5305 113.45	6.3	3.1	1.8	0.61	0.60	1.7	0.59	0.52	0.03	3.6
Scripps 36B-21A	6.5	3.0	1.9	0.59	0.59	1.4	0.54	0.53	0.03	3.6
5005-130.40	6.7	3.5	2.2	0.80	0.71	1.8	0.72	0.53	0.07	3.8
5206 80.60	6.9	3.3	2.2	0.78	0.62	1.7	0.60	0.60	0.06	4.1
5604 83.70	7.0	3.6	2.3	0.81	0.76	1.8	0.70	0.66	0.08	4.2
5206 93.50	7.4	4.0	2.5	0.89	0.75	1.8	0.80	0.75	0.12	4.5
5306 85.60	7.6	4.2	2.5	0.91	0.79	2.1	0.84	0.84	0.13	4.5
5704 100.60	7.7	4.6	3.1	1.1	0.80	2.2	1.0	0.80	0.18	5.0
5303 80.60	7.9	4.7	2.8	1.1	0.86	2.2	0.91	0.86	0.18	5.0
5605 93.70	8.0	4.7	3.0	1.1	0.85	2.2	1.0	0.83	0.24	5.0
7507 90.70	8.3	5.0	3.1	1.1	1.0	2.4	1.0	0.95	0.18	5.3
5706 73.90	8.6	5.0	3.2	1.2	0.90	2.2	1.0	0.86	0.30	5.4
7712 90.26	8.8	4.9	2.9	1.0	0.95	2.3	1.0	0.91	0.22	5.4
5304 127.40	9.4	5.3	3.2	1.2	0.92	2.7	1.1	1.0	0.34	5.6
7807 63.60	9.8	6.1	3.8	1.4	1.1	2.9	1.3	1.1	0.50	6.1
8107 70.90	10.3	6.5	4.1	1.4	1.2	3.2	1.4	1.1	0.68	6.5
LACM 9674-16	10.5	6.9	4.2	1.5	1.2	3.4	1.8	1.0	0.90	6.9
8107 76.7.70	11.3	6.9	4.3	1.6	1.3	3.8	1.8	1.2	1.0	6.9
7808 93.60	11.9	7.7	4.7	1.6	1.3	3.6	2.1	1.2	1.0	7.7
H49 123.50	12.4	7.9	4.8	1.7	1.4	4.0	1.9	1.2	1.4	7.9
LACM 302-70-9	13.5	8.8	5.5	2.0	1.4	4.3	2.6	1.2	1.5	8.8
8101 76.7.50	13.7	8.3	5.4	1.9	1.6	4.3	2.4	1.2	1.7	8.3
LACM 30202-7	14.2	8.8	5.4	1.8	1.6	4.6	2.9	1.3	1.6	8.8
7510 88.60	14.7	9.5	5.8	1.8	1.8	4.6	3.1	1.5	2.1	9.5
LACM 9677-11	15.7	9.8	6.2	2.2	1.8	4.8	3.2	1.3	2.2	9.8
LACM 9497-11	17.9	11.3	6.8	2.2	1.8	5.2	4.1	1.7	2.7	11.3
LACM 30202-7	18.6	11.3	7.1	2.5	2.0	5.6	4.1	1.6	2.9	11.5
5103 98.40	21.5	14.4	7.8	2.5	2.2	7.0	4.8	1.9	3.4	14.4
LACM 30203-3	23.1	15.2	9.6	---	2.5	6.8	5.5	1.8	4.0	15.9
LACM 9943-17	27.3	16.9	10.0	2.8	2.9	9.2	6.7	2.5	4.8	17.7
LACM 36313-1	28.3	17.9	10.0	3.2	2.8	9.2	6.9	2.5	4.6	18.6
LACM 36303-1	34.4	22.0	12.8	4.2	3.3	11.2	8.6	2.9	5.9	23.3
SIO 84-47*	38.3	23.7	13.2	3.4	4.1	11.3	10.1	3.2	6.9	25.5
SIO 70-350*	38.9	23.0	13.8	3.2	4.2	11.8	8.6	3.2	6.2	25.5

*Benthic juvenile.

Table 2. Comparative morphometry of six species of Sebastes. Data from Moser et al. 1977, Moser and Butler 1981, and this study.

Species		Snout to anus distance / Body length	Head length / Body length	Snout length / Head length	Eye diameter / Head length	Body depth / Body length	Pectoral fin length / Body length	Pectoral fin base depth / Body length	Pelvic fin length / Body length
S. aurora	A	43.6 ± 3.46(38-49)	25.9 ± 3.38(21-30)	29.5 ± 3.86(23-37)	33.7 ± 2.87(29-39)	19.9 ± 3.20(15-27)	7.6 ± 1.34(5-10)	7.0 ± 0.96(6- 9)	(1
	B	56.3 4.69(48-62)	35.2 2.66(32-40)	36.2 1.40(35-39)	30.0 2.36(26-33)	27.0 1.70(25-29)	11.4 1.26(9-13)	9.9 0.99(8-11)	1.9 ± 0.74(1- 3)
	C	61.6 3.81(56-66)	37.8 2.71(33-40)	35.6 1.60(34-38)	29.5 1.51(28-33)	30.5 2.39(26-34)	14.5 2.45(11-18)	10.5 0.53(10-11)	7.0 2.78(3-11)
	D	63.4 1.98(61-67)	38.2 1.96(35-41)	32.9 2.30(28-36)	28.0 1.91(25-31)	31.2 1.60(29-34)	21.9 2.35(18-25)	8.8 0.58(8-10)	14.8 2.38(11-18)
S. dallii	A	42.4±0.52(42-43)	22.6±1.06(21-24)	25.6±3.02(19-29)	38.0±1.85(35-41)	17.6±1.85(15-20)	5.6±0.52(5- 6)	5.9±1.36(3- 7)	—
	B	45.7 2.07(43-48)	26.5 1.38(25-29)	28.7 1.86(27-32)	37.8 1.33(36-40)	20.7 2.07(18-23)	8.0 0.63(7- 9)	8.3 0.82(7- 9)	1.26±0.73(0.3-2.1)
	C	50.8 3.27(48-56)	30.6 1.95(28-33)	30.4 0.89(29-31)	36.8 1.92(34-39)	23.8 2.68(22-28)	11.0 2.45(9-14)	10.2 0.84(9-11)	4.0 2.83(2- 9)
	D	57.0 1.41(56-58)	29.5 0.71(29-30)	33.0 0.00(33)	33.5 0.71(33-34)	25.0 0.00(25)	23.5 0.71(23-24)	8.0 0.00(8)	15.5 0.71(15-16)
S. jordani	A	36.5 0.84(36-38)	22.3 1.51(21-25)	26.8 3.43(23-31)	37.7 0.82(36-38)	17.0 1.26(16-19)	6.7 0.52(6- 7)	6.5 0.55(6- 7)	—
	B	42.4 1.67(41-45)	28.4 2.19(26-30)	35.5 1.29(34-37)	32.2 ? 50(29-35)	21.0 1.00(20-22)	8.4 1.14(7-10)	7.8 0.45(7- 8)	1.4 0.55(1- 2)
	C	51.0 2.86(46-54)	32.3 1.44(31-36)	34.4 1.98(31-39)	29.3 2.10(27-34)	23.8 1.19(22-26)	16.8 3.25(11-20)	7.9 1.00(7-10)	9.0 3.62(3-13)
	D	53.3 1.03(52-55)	31.2 1.94(28-33)	34.0 2.83(30-38)	26.5 1.52(24-28)	22.2 0.84(21-23)	20.5 1.05(19-22)	7.0 0.00(7)	13.5 1.22(12-15)
S. levis	A	39.6 2.30(37-44)	24.7 1.60(23-28)	30.7 2.63(27-35)	33.1 2.67(29-36)	21.7 1.11(20-23)	17.4 5.29(11-24)	10.9 1.57(8-13)	—
	B	48.9 3.44(45-56)	30.5 1.85(28-33)	34.8 0.87(34-36)	32.5 1.77(30-35)	28.5 3.51(24-35)	34.9 6.96(24-46)	12.9 0.64(12-14)	6.1 3.27(2-12)
	C	59.2 2.87(57-63)	35.0 2.00(34-38)	30.2 2.22(28-33)	30.5 1.73(28-32)	34.0 1.41(33-36)	45.0 3.74(41-50)	11.2 0.96(10-12)	21.0 4.76(16-26)
	D	63.0 0.82(62-64)	33.8 0.96(33-35)	30.5 2.38(28-33)	27.0 3.37(25-32)	35.0 1.41(34-37)	40.8 7.09(32-47)	10.2 0.96(9-11)	24.2 2.87(22-28)
S. macdonaldi	A	42.4 3.53(36-47)	27.6 2.25(24-31)	30.6 4.16(25-36)	34.6 2.34(31-37)	23.1 3.99(13-27)	8.4 1.21(6-10)	—	1.8 0.84(1- 3)
	B	51.8 3.56(48-56)	35.6 1.52(34-38)	34.0 4.00(30-38)	32.0 1.41(31-34)	31.6 2.07(30-35)	13.0 1.22(12-15)	—	5.8 2.39(3- 9)
	C	60.3 3.06(55-64)	37.5 1.84(34-41)	32.9 3.00(29-37)	33.0 1.33(31-35)	34.4 1.17(33-36)	19.3 3.65(15-26)	—	14.3 3.77(10-21)
	D	64.2 2.44(61-68)	35.1 2.37(32-38)	27.9 2.09(25-32)	30.7 2.74(26-34)	31.4 1.59(30-34)	30.4 1.74(28-34)	—	21.9 1.36(21-25)
S. paucispinis	A	41.0 2.74(37-44)	26.8 2.28(24-29)	27.4 3.21(24-32)	32.8 3.77(29-37)	19.6 1.67(17-21)	16.4 4.56(11-21)	9.0 0.71(8-10)	5.3 4.93(2-11)
	B	44.8 3.70(40-49)	29.6 1.95(27-32)	30.6 1.82(29-33)	30.2 1.64(29-33)	23.0 1.41(21-24)	27.2 2.49(25-31)	9.0 0.71(8-10)	13.6 9.28(9-26)
	C	57.3 3.82(51-61)	37.1 1.07(36-39)	32.2 0.98(31-33)	31.3 1.70(28-33)	29.6 0.98(28-31)	35.7 1.25(34-37)	7.6 0.53(7- 8)	35.1 2.79(31-39)
	D	62.3 2.73(60-66)	36.2 1.72(33-38)	30.5 2.95(26-33)	27.8 1.72(26-30)	27.3 0.52(27-28)	28.2 3.40(25-34)	6.0 0.89(5- 7)	25.2 2.71(22-30)

[1]A = preflexion larvae; B = larvae undergoing notochord flexion; C = postflexion larvae; D = pelagic juveniles

Table 3. Sequence of Development of Head Spines of Sebastes aurora.

Spine	Order of appearance	Size (mm) (body length) at appearance	Size (mm) (body length) when lost
pterotic	1	5.0	---
2nd anterior preopercular	2	5.3	18.6
3rd posterior preopercular	2	5.3	---
4th anterior preopercular	3	5.6	18.6
2nd posterior preopercular	3	5.6	---
parietal	3	5.6	---
postocular	3	5.6	---
4th posterior preopercular	4	6.1	---
5th posterior preopercular	5	8.0	---
lower posttemporal	5	8.0	---
1st upper infraorbital	5	8.0	27.3
1st lower infraorbital	5	8.0	---
upper opercular	5	8.0	---
nuchal	6	8.9	---
1st posterior preopercular	7	10.5	---
2nd lower infraorbital	7	10.5	---
supercleithrum	7	10.5	---
preocular	7	10.5	---
4th upper infraorbital	8	12.7	27.3
nasal	8	12.7	---
upper posttemporal	9	15.2	---
interopercular	9	15.2	---
lower opercular	10	18.6	---
supraocular	10	18.6	---
tympanic	10	18.6	---
coronal	10	18.6	---
cleithral	11	34.4	---

Table 4. Meristics of Cleared and Stained Specimens of Sebastes aurora.

Length (mm)	Principal caudal fin rays		Procurrent caudal fin rays		Branchio-stegal rays		Pectoral fin rays		Gill rakers (right arch)		Anal fin rays	Dorsal fin rays	Pelvic fin rays		Vertebrae
	superior	inferior	superior	inferior	left	right	left	right	upper limb	lower limb			left	right	
5.3	1	1	--	--	1	1	--	--	--	--	--	--	--	--	1
5.6	3	3	--	--	4	4	2	2	--	5	--	--	--	--	2
6.1	4	4	--	--	4	4	5	5	--	5	--	--	--	--	4
6.2	5	5	--	--	5	4	6	6	--	6	--	--	--	--	7
6.6	6	6	--	--	6	6	7	7	--	7	--	--	--	--	14
7.2	7	7	--	--	7	7	12	12	--	7	--	--	--	--	22
7.5	7	7	--	--	6	6	9	9	--	7	--	--	--	--	21
8.0	8	7	1	2	7	7	14	14	2	12	I,4	I, 9	I,2	I,2	24
8.3	"	"	4	4	"	"	16	17	3	14	III,5	XII,12	I,4	I,4	26
8.9	"	"	3	3	"	"	16	16	3	12	III,5	XII,13	I,4	I,4	25
9.4	"	"	4	4	"	"	17	17	3	12	III,6	XIII,13	I,4	I,4	26
10.5	"	"	7	7	"	"	17	17	5	15	III,6	XIII,13	I,5	I,5	"
11.3	"	"	7	7	"	"	18	18	4	14	III,7	XIII,13	"	"	"
12.7	"	"	8	8	"	"	18	18	5	14	III,6	XIII,13	"	"	"
13.7	"	"	9	9	"	"	17	18	7	17	"	XIII,12	"	"	"
14.2*	"	"	10	10	"	"	17	17	7	17	"	XIII,13	"	"	"
15.2*	"	"	10	10	"	"	17	17	6	16	"	XIII,13	"	"	"
18.6*	"	"	10	11	"	"	17	17	8	18	"	XIII,13	"	"	"
21.5*	"	"	10	10	"	"	18	18	8	18	"	XIII,13	"	"	"
27.3*	"	"	10	10	"	"	18	18	7	17	"	XIII,13	"	"	"
28.3*	"	"	10	10	"	"	17	17	8	17	"	XIII,13	"	"	"
34.4*	"	"	10	10	"	"	18	18	9	18	"	XIII,12	"	"	"
38.9**	"	"	10	9	"	"	18	18	7	18	-	XIII,13	"	"	"

*Pelagic juvenile.
**Demersal juvenile.

Kendall, A.W., Jr. and J.B. Marliave (editors). 1985. Descriptions of early life history stages of selected fishes: from the 3rd International Symposium on the Early Life History of Fishes and 8th Annual Larval Fish Conference, May 1984, University of British Columbia, Vancouver, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 1359: 62 p.

Descriptive Characteristics of Reared *Sebastes caurinus* and *S. auriculatus* Larvae

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Two species of rockfish from the northeast Pacific Ocean, *Sebastes caurinus* (copper rockfish) and *S. auriculatus* (brown rockfish), were reared from birth to complete caudal fin formation using laboratory-cultured rotifers, *Brachionus plicatilis*, and nauplii of the brine shrimp, *Artemia salina*, and are described here. These descriptions add to the short list of species of *Sebastes* for which larvae have been described.

Serial descriptions of larval development of 15 northeast Pacific *Sebastes* species are presently available, described primarily from specimens collected by ichthyoplankton surveys:

- -Moser et al. (1977): *S. cortezi*, *S. levi*, *S. jordani*, *S. macdonaldi*, *S. paucispinis*, and *Sebastes* Gulf of California Type A.
- -Moser and Ahlstrom (1978): *S. melanostomus*.
- -Richardson and Laroche (1979): *S. crameri*, *S. helvomaculatus* and *S. pinniger*.
- -Laroche and Richardson (1980): *S. flavidus* and *S. melanops*.
- -Laroche and Richardson (1981): *S. entomelus* and *S. zacentrus*.
- -Moser (this volume): *S. aurora*.

In addition, Moser and Butler (1981) described *S. dallii* from laboratory-reared larvae fed wild plankton. Rotifers and brine shrimp nauplii were used by Hoshiai (1977) while rearing *S. schlegeli*, a northwestern Pacific species.

Materials and Methods

Sebastes caurinus and *S. auriculatus* larvae were obtained at birth from gestating females held in isolation in the laboratory. They were reared in 100-l circular fiberglass tanks stocked at an initial density of 5 larvae/l. Open water systems were used to regulate temperatures which ranged from 11.5 to 16.5°C with means of 13.7 to 15°C among three broods.

Rotifers cultured on the phytoplankton *Tetraselmis* sp. were fed to the larvae each morning at densities of 15-20 rotifers/ml. Brine shrimp nauplii were initially fed at a density of 1 nauplius/4 mls which was gradually increased to 1/ml. In the open systems food was lost at an average rate of 14% per hour. Food organisms were collected from the out-flow traps of each container and returned to the rearing tanks at 2-3 hour intervals. This periodic reintroduction of food created temporary "patches" which enhanced larval feeding activity.

The developing larvae were sampled at 4-5 day intervals. Morphometric characteristics were obtained following the methods of Richardson and Laroche (1979), using their categories of caudal fin development as well; i.e., preflexion, flexion and postflexion. None of these larvae were reared beyond the completion of notochord flexion and caudal fin formation. Differences in body proportions between species by flexion category were compared using analysis of variance.

The occurrence and distribution of larval melanophores were examined for both species from birth through caudal fin formation. The number and location of the melanophores on 35 newborn larvae of each species were analyzed to investigate initial differences between them. Newborn melanophore patterns were compared by use of either the Chi-square distribution or the predictive sample reuse model of Giesser and Eddy (1979). Four drawings of each species were sketched through a camera lucida to illustrate the development of these patterns with growth.

The development of meristic characteristics was examined by clearing and staining a developmental series of each species using the Dingerkus and Uhler (1977) technique of differential staining for cartilage and bone.

Results

Morphometrics

When the morphometrics (Tables 1 and 2) are compared as proportions of standard length or head length by flexion category (Table 3) significant differences between *S. caurinus* and *S. auriculatus* larvae are found in the preflexion category. These include a larger

Table 1. Mean dimensions within 0.5 mm size intervals of reared larvae of Sebastes caurinus. Notochord flexion occurring in larvae between the dashed lines.

Size interval SL mm	Sample size	Measurements 1/ mm													
		SL	TL	SA	HL	ED	SNL	UJ 2/	PD	AD	PFL 3/	PVL	PVI	PPO3	PA
5.00 - 5.50	7	5.39	5.68	2.14	1.14	0.42	0.32	0.56	0.89	0.80					
5.50 - 6.00	26	5.71	6.01	2.26	1.24	0.45	0.34	0.54	0.95	0.84				0.07	
6.00 - 6.50	17	6.18	6.57	2.63	1.58	0.58	0.46	0.70	1.19	1.00				0.09	
6.50 - 7.00	16	6.74	7.25	2.92	1.80	0.66	0.56	0.84	1.38	1.11		0.27	2.17	0.19	+
7.00 - 7.50	11	7.27	8.21	3.51	2.22	0.82	0.66	1.02	1.73	1.48		0.25	2.33	0.38	0.10
7.50 - 8.00	5	7.75	8.66	3.69	2.41	0.88	0.69	1.14	1.84	1.59		0.33	2.49	0.41	0.11
8.00 - 8.50	3	8.22	9.66	4.12	2.81	1.03	0.76	1.29	2.06	1.88		0.36	2.60	0.48	0.32
8.50 - 9.00	1	8.63	9.47	4.18	2.88	1.04	0.88	1.30	2.04	1.72	0.79	0.51	2.83	0.46	0.23
9.00 - 9.50	1	9.26	10.38	5.03	3.17	0.86	0.72	1.26	2.68	1.97	0.94	0.56	3.72	0.67	0.44
9.50 - 10.00	1	9.56	10.95	4.70	3.25	1.25	0.93	1.53	2.41	1.90	0.93	1.02	3.16	0.65	0.37

1/ SL=standard length; TL=total length; SA=snout to anus length; HL=head length; ED=eye diameter; SNL=snout length; UJ=upper jaw length; PD=depth at pectoral fin; AD=depth at anus; PFL=pectoral fin length; PVL=pelvic fin length; PVI=pelvic fin insertion; PPO3=third posterior preopercular spine length; PA=parietal spine length

2/ Upper jaw measurements not accurate for larvae less than 6.00 mm.

3/ Only reliable measurements of pectoral fins reported.

Table 2. Mean dimensions within 0.5 mm size intervals of reared larvae of Sebastes auriculatus. Notochord flexion occurring in larvae between the dashed lines.

Size interval SL mm	Sample size	Measurements 1/ mm													
		SL	TL	SA	HL	ED	SNL	UJ 2/	PD	AD	PFL 3/	PVL	PVI	PPO3	PA
5.00 - 5.50	7	5.37	5.65	2.43	1.19	0.51	0.36	0.54	1.04	0.86		-	-	-	-
5.50 - 6.00	24	5.67	5.98	2.52	1.32	0.52	0.39	0.60	1.05	0.88		-	-	0.09	+
6.00 - 6.50	7	6.24	6.55	2.82	1.65	0.59	0.48	0.66	1.22	0.98		-	-	0.18	+
6.50 - 7.00	12	6.73	7.11	3.08	1.96	0.70	0.56	0.88	1.39	1.10	0.59			0.25	0.12
7.00 - 7.50	8	7.31	8.08	3.55	2.39	0.87	0.69	1.17	1.70	1.41	0.67	0.32	2.55	0.44	0.21
7.50 - 8.00	14	7.72	8.60	3.77	2.48	0.90	0.68	1.21	1.82	1.48	0.66	0.37	2.49	0.43	0.24
8.00 - 8.50	7	8.35	9.57	4.17	2.74	0.99	0.76	1.32	2.03	1.73	0.77	0.47	2.69	0.53	0.28
8.50 - 9.00	4	8.69	9.95	4.47	2.94	1.04	0.80	1.41	2.03	1.76	0.76	0.61	2.84	0.52	0.31
9.00 - 9.50	2	9.11	10.47	4.64	3.04	1.10	0.82	1.61	2.18	1.89	0.88	0.54	3.17	0.58	0.34

1/ SL=standard length; TL=total length; SA=snout to anus length; HL=head length; ED=eye diameter; SNL=snout length; UJ=upper jaw length; PD=depth at pectoral fin; AD=depth at anus; PFL=pectoral fin length; PVL=pelvic fin length; PVI=pelvic fin insertion; PPO3=third posterior preopercular spine length; PA=parietal spine length

2/ Upper jaw measurements not reliable for larvae less than 6.00 mm SL.

3/ Only reliable measurements of pectoral fins reported here.

Table 3. Comparison of the body proportions of the reared larvae of Sebastes caurinus and S. auriculatus as percent standard length (SL) or head length (HL) by flexion category, reported as the mean ± 2 S.E. and the range in parentheses.

Dimension	Sebastes caurinus	Sebastes auriculatus	df	F ratio/ t-value[3/]	Prob.
Body depth at pectoral fin/SL:					
Preflexion	18.3 ± 0.33 (13.1-24.7)	19.9 ± 0.61 (15.8-26.3)	1,219	23.63	<0.001
Flexion	22.9 ± 0.75 (18.8-28.0)	22.7 ± 0.86 (18.8-25.1)	1,44	0.17	0.68
Postflexion[1/]	24.2 ± 0.70 (21.0-28.9)	24.3 ± 0.63 (22.1-28.9)	1,41	0.02	0.85
Body depth at anus/SL:					
Preflexion	15.5 ± 0.26 (10.8-21.1)	16.0 ± 0.42 (12.9-20.7)	1,219	4.97	0.02
Flexion	19.4 ± 0.96 (14.1-24.2)	18.5 ± 0.99 (12.9-21.0)	1,44	1.15	0.29
Postflexion[1/]	20.8 ± 0.76 (17.4-25.8)	20.6 ± 0.51 (18.0-22.8)	30.4	0.32*	0.75
Snout to anus length/SL:					
Preflexion	40.9 ± 0.36 (36.0-47.1)	45.4 ± 0.41 (42.6-51.0)	145.4	-16.72*	<0.001
Flexion	47.1 ± 0.91 (42.8-52.0)	47.6 ± 0.95 (44.5-50.7)	1,44	0.45	0.51
Postflexion[1/]	49.0 ± 1.07 (42.3-54.3)	50.4 ± 0.73 (47.2-53.4)	32.4	-2.61*	0.01
Snout to pelvic fin origin/SL:					
Preflexion	31.4 ± 3.17 (28.3-33.5)	31.2 ± 0.83 (28.7-33.1)	1,12	0.03	0.83
Flexion	32.2 ± 1.22 (28.4-40.8)	32.6 ± 1.54 (29.1-37.8)	1,36	0.21	0.66
Postflexion[1/]	33.0 ± 1.00 (28.6-40.2)	33.2 ± 0.77 (31.1-37.9)	33.5	0.03*	0.97
Head length/SL:					
Preflexion	23.4 ± 0.42 (19.0-30.6)	25.5 ± 0.88 (19.4-32.0)	85.6	-4.44*	<0.001
Flexion	30.1 ± 0.80 (25.8-36.1)	31.0 ± 1.03 (27.5-34.4)	1,44	1.73	0.19
Postflexion[1/]	32.4 ± 0.76 (29.2-36.3)	33.7 ± 1.01 (29.8-37.9)	1,41	4.79	0.03
Eye diameter/HL:					
Preflexion	36.3 ± 0.39 (29.7-44.6)	38.2 ± 0.90 (31.9-46.5)	80.7	-3.87*	<0.001
Flexion	36.9 ± 1.05 (32.8-42.6)	37.0 ± 1.16 (34.1-43.6)	1,41	0.001	0.92
Postflexion[1/]	37.0 ± 1.04 (29.9-41.5)	35.9 ± 0.51 (33.8-39.5)	17.6	1.82	0.08
Upper jaw length/HL:					
Preflexion	42.0 ± 1.14 (29.7-57.6)	42.8 ± 1.92 (32.6-52.6)			
Flexion	47.1 ± 1.65 (37.4-57.3)	50.0 ± 1.80 (44.7-56.4)	1,40	4.62	0.04
Postflexion[1/]	46.9 ± 1.82 (42.9-54.2)	48.6 ± 1.46 (42.9-55.8)	1,35	2.14	0.15

Table 3. Continued

Dimension	*Sebastes caurinus*	*Sebastes auriculatus*	df	F ratio/ t-value[3/]	Prob.
Snout length/HL:					
Preflexion	28.6 ± 0.38 (20.6-38.1)	29.5 ± 0.61 (23.3-34.2)	1,217	6.11	0.01
Flexion	29.5 ± 0.80 (25.8-32.9)	28.0 ± 1.11 (24.3-32.1)	1,41	5.04	0.03
Postflexion[1/]	27.9 ± 0.80 (25.0-31.9)	27.7 ± 0.82 (23.4-30.3)	1,35	0.10	0.75
Pectoral fin length/SL:[2/]					
Preflexion	9.3 ± 0.45 (5.4-15.8)	13.9 ± 1.16 (7.0-22.0)			
Flexion	10.7 ± 1.38 (5.2-20.6)	8.6 ± 0.42 (6.4- 9.7)			
Postflexion[1/]	10.1 ± 1.07 (7.7-19.1)	9.1 ± 0.33 (6.9-10.2)	22.4	1.73*	0.10
Pelvic fin length/SL:					
Preflexion	3.2 ± 0.32 (2.8- 3.8)	2.3 ± 0.51 (1.1- 4.0)	1,14	5.08	0.04
Flexion	3.8 ± 0.33 (1.1- 5.4)	4.1 ± 0.54 (2.9- 5.9)	1,42	0.95	0.34
Postflexion[1/]	5.3 ± 0.52 (3.6-10.7)	5.8 ± 0.36 (4.5- 8.5)	31.6	-1.74*	0.09
Parietal spine length/HL:					
Preflexion	0.5 ± 0.02 (0.5- 0.6)	2.7 ± 1.30 (0.5-10.0)			
Flexion	5.4 ± 1.74 (0.5-12.8)	8.3 ± 1.54 (0.5-12.2)			
Postflexion[1/]	10.1 ± 0.90 (6.1-14.9)	10.3 ± 0.59 (5.8-11.7)	25.7	-0.78*	0.44
Preopercular spine length/HL:					
Preflexion	7.4 ± 1.7 (0.5-17.9)	12.3 ± 1.86 (0.6-18.1)			
Flexion	16.6 ± 1.0 (9.8-23.3)	17.3 ± 1.30 (11.8-22.8)	1,44	0.71	0.41
Postflexion[1/]	18.1 ± 0.94 (13.0-23.6)	18.3 ± 0.85 (14.5-22.4)	1,41	0.55	0.47

1/ Postflexion larvae are those which have completed caudal fin formation; none here had grown significantly beyond this point.
2/ Pectoral fin measurements prior to the postflexion stage wanted in accuracy and are considered unreliable for comparative purposes.
3/ If variances were determined to be unequal (*), a t-test with separate variances was applied.

head and deeper body in S. auriculatus than in S. caurinus, but most differences disappear with the onset of flexion. A few statistically significant differences were found between species in the flexion and postflexion categories but these are small and the ranges of the proportions overlap substantially.

Pigment Patterns

Newborn larvae of both species are pigmented on the dorsal and ventral midlines, the lower jaw, the brain lobes , the nape, and the dorsal and ventral surfaces of the gut (Figures 1 and 2). They differ in the amount of pigment over the optic lobes, the otic capsules, and the dorsal midline (Table 4), but the number of dorsal midline melanophores and their distribution on the preanal myomeres are the most reliable characteristics for separating the two species. The dorsal midline in newborn S. caurinus larvae has more melanophores which are distributed as far forward as the first preanal myomere, in contrast to S. auriculatus larvae which have no pigment over the preanal myomeres at birth.

The head region of both species gains pigment rapidly during development. At 6.3 mm the only true distinction between the two is the extent of the dorsal midline pigment; the entire dorsal surface of S. caurinus is pigmented while the preanal myomeres of S. auriculatus remain unpigmented. This difference, however, loses its significance in 7.5 mm larvae when a patch of pigment begins to form over the 3rd to 5th myomeres of S. auriculatus larvae. Still there is not as much pigment here as in S. caurinus. At this same stage the head pigmentation becomes distinctive, transferring the focus of distinguishing characteristics to the opercular and mandibular regions.

The preopercular spines and the mandibles of both species are pigmented at 7.5 mm, but more so in S. auriculatus. With growth, the preopercular spines of of S. caurinus remain sparsely pigmented while extensive pigmentation occurs on the same spines of S. auriculatus. The most apparent contrast, however, is found in the patch of pigment developing on the cheek anterior to the preopercle of S. auriculatus which becomes prominant at complete flexion. No patch develops here in reared S. caurinus larvae; the few melanophores which appear posterior to the orbit during postflexion remain above the horizontal midline of the eye.

The extent and location of pigment on the operculum also contrast between the two species in early postflexion. S. caurinus has one central patch of melanophores on the operculum; S. auriculatus has an upper and lower patch on the same structure. Generally, S. auriculatus has developed more head pigment at complete flexion than S. caurinus. The pectoral fins of S. auriculatus are also pigmented in smaller larvae than in S. caurinus, 6.3 vs 7.5 mm, respectively, beginning on the interior surfaces of the radial lobes in both species.

The only distinct contrast in trunk pigment between these species during early postflexion is again in the dorsal midline pigment, which becomes the reverse of the newborn stage. That is, a patch of melanophores develops over the anterior myomeres of S. auriculatus, and melanophores recede from the same location in S. caurinus.

Meristic Characteristics

Most of the adult meristic features of S. caurinus and S. auriculatus are present in early postflexion larvae (Tables 5 and 6). The characteristics lacking their complete structural complements at 9.5 mm in either species are the secondary caudal fin rays, the dorsal and pelvic fin spines and rays, and the gill rakers. S. caurinus also lacked one of the 15 heamal spines. The rates of appearance and calcification of individual bones varied slightly between species but this may have been an artifact of the rearing environment. The branchiostegal rays are the only sets of bones that are completely formed and calcified in these series.

Discussion

Differences in larval pigmentation were the only substantial identifying characteristics which appeared to be useful to separate S. caurinus and S. auriculatus larvae. The ranges in the morphometric characteristics overlapped between species so that the observed statistical differences are not practical for separating field-caught specimens.

The pigment patterns reported by DeLacy et al. (1964) for force-extruded S. caurinus and S. auriculatus larvae hold true for the newborn larvae described in this study. However, the dorsal midline counts reported by Moser et al. (1977) of prematurely extruded larvae at yolk absorption are the exact opposite of what I report for these two species. Their counts were also opposite to those given by Delacy et al. (1964). This reversal is apparent in the

Table 4. Differences in pigment patterns of Sebastes caurinus and S. auriculatus larvae less than 24 hours old.

Number of melanophores present on the dorsal surfaces:

Location	S. caurinus $\bar{x}$ (range),n	S. auriculatus $\bar{x}$ (range),n	
Optic lobes	1.3, (0-4), 36	6.4, (3-10), 35	$D_1 > D_2$
Medulla	2.3, (1-5), 36	2.2, (0-8), 35	$D_1 \leq D_2$
Otic capsule	0, (1-0), 36	1.1, (0-3), 35	$D_1 > D_2$
Dorsal midline	22.5, (18-32), 17	15.0, (12-22), 23	$D_1 > D_2$
First myomere with dorsal pigment	4.7, (1-8), 20	10.7, (7-14), 23	$D_1 > D_2$

1/ Predictive sample reuse model after Geisser and Eddy (1979).

H_o: Populations are identical

H_a: Populations are distinct

If $D_1 \leq D_2$; then H_o

If $D_1 > D_2$; then H_a

Presence or absence of melanophores on:

	+ , -	+ , -	Adjusted Chi-squared analysis; Two-way contingency table
Angle of lower jaw	1 , 35	13 , 22	$G_{ADJ} = 12.42$ $P < 0.005$
Mandibular symphosis	14 , 22	31 , 4	$G_{ADJ} = 17.89$ $P < 0.005$
Cleithral symphosis	9 , 25	29 , 6	$G_{ADJ} = 21.05$ $P < 0.005$
Lateral trunk surface	10 , 15	24 , 1	$G_{ADJ} = 17.32$ $P < 0.005$

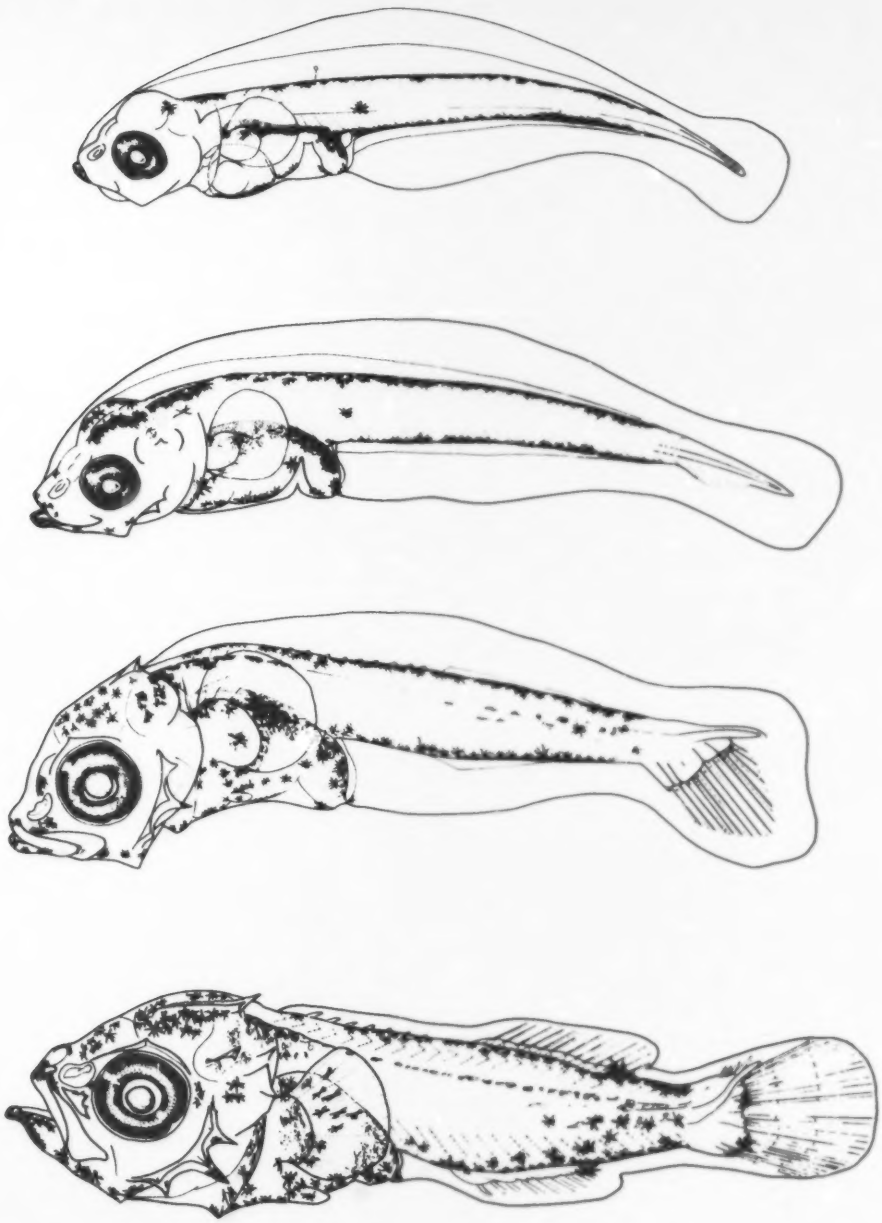

Figure 1. Sebates caurinus larvae: A.) newborn at 5.3 mm; B.) 6.3 mm at 9 days, preflexion; C.) 7.5 mm at 21 days, early flexion; D.) 9.5 mm at 35 days, early postflexion.

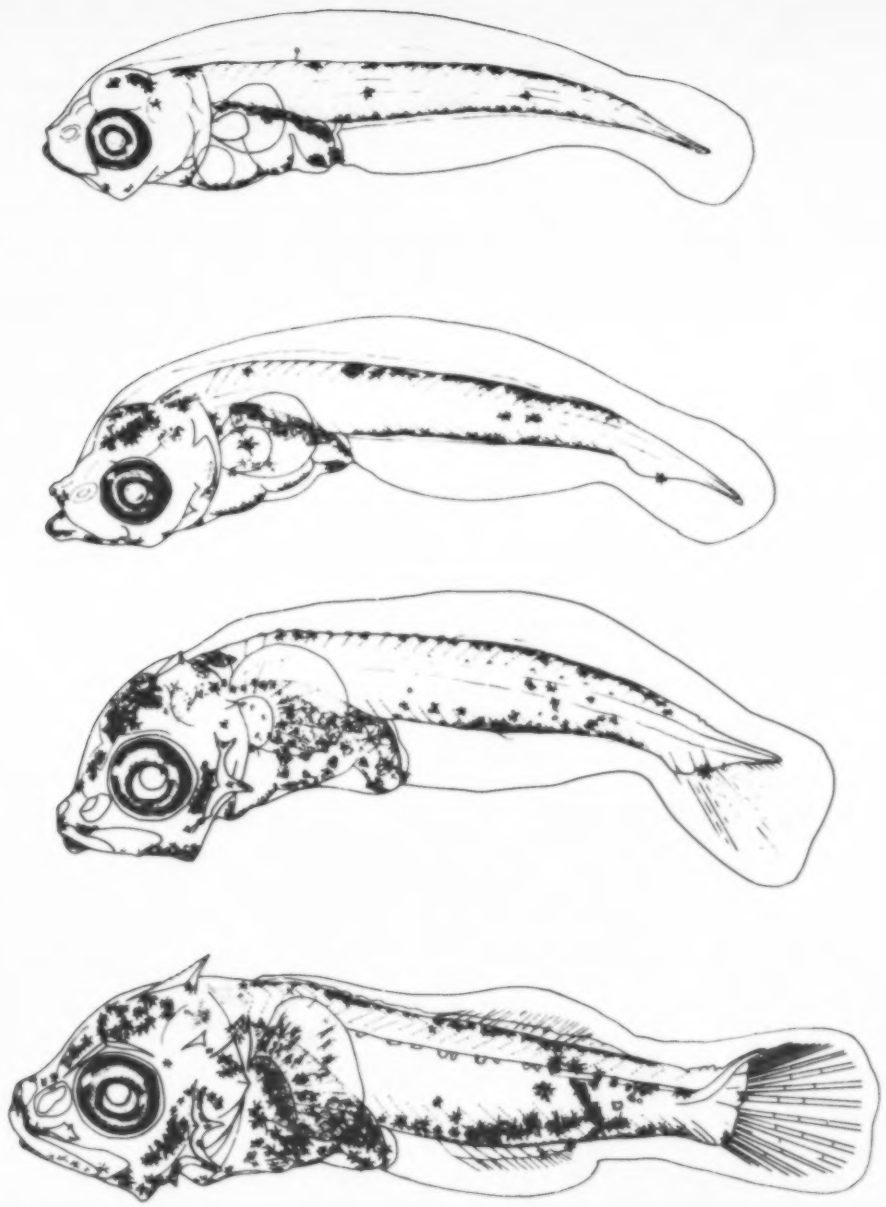

Figure 2. Sphaeramia auriculatus larvae: A.) newborn at 5.5 mm; B.) 6.3 mm at 8 days, preflexion; C.) 7.4 mm at 18 days, early flexion; D.) 9.0 mm at 24 days, early postflexion.

Table 5. Development of meristic characters of reared larvae of Sebastes caurinus. Counts are of individual larvae. The ratio X/Y represents those elements that stained blue (X) vs those stained red (Y). Adult counts from radiographs of 2 adults and 4 juveniles are included. Where counts varied, means are reported with ranges in parentheses.

mm SL	1° Caudal Rays		2° Caudal Rays		Left Branchio-stegal Rays	Left Pectoral Fin Rays	Hypural Elements		Epurals
	Superior	Inferior	Superior	Inferior			Superior	Inferior*	
5.3	0	0	0	0	0	0	0	0	0
6.5	0	0	0	0	3/0	0	0	3/0	0
6.9	2/0	4/0	0	0	4/0	0	1/0	3/0	0
7.5	3/0	5/0	0	0	5/0	0	1/0	3/0	0
8.0	6/0	6/0	0	1/0	2/4	9/0	2/0	3/0	3/0
8.5	8/0	7/0	0	1/0	3/4	12/0	2/0	3/0	3/0
9.5	6/2	4/3	2/0	2/0	0/7	15/0	3/0	3/0	3/0
Adult	8	7	10 (9-11)	10 (9-11)	7	17 (16-18)	3	3	3

mm SL	Anal Fin	Dorsal Fin	Left Pelvic Fin	Vertebral Centra		Neural		Haemal		Rakers 1st Arch
				Precaudal	Caudal	Spines	Arches	Spines	Arches	
5.3	0	0	0	0	0	0	0	0	0	
6.5	0	0	0	0	0	0	0	0	0	
6.9	0	0	0	0	0	0	0	14/0	14/0	
7.5	0	0	0	0	0	0	3/0	14/0	18/0	
8.0	2/0	8/0	0	10/0	0	24/0	24/0	14/0	19/0	4/0
8.5	8/0	10/0	0	7/3	10/0	24/0	18/6	14/0	19/0	7/0
9.5	III,6/0	VII,12/0	I,3/0	5/5	16/0	24/0	17/8	14/0	11/8	3/10
Adult	III,5 (6)	XIII,13 (11-14)	I,5	10	16	24	25	15	19	26-32

* Inferior hypural elements include parhypural.

Table 6. Development of the meristic characters of reared larvae of Sebastes auriculatus. Counts are of individual larvae. The ratio X/Y represents those elements that stained blue (X) vs those that stained red (Y). Adult counts from radiographs of 2 adults and 15 juveniles are included. Where counts varied, means are reported, ranges in parentheses.

mm SL	1° Caudal Rays		2° Caudal Rays		Left Branchio-stegal Rays	Left Pectoral Fin Rays	Hypural Elements		Epurals
	Superior	Inferior	Superior	Inferior			Superior	Inferior*	
5.5	0	0	0	0	0	0	0	0	0
6.3	0	0	0	0	2/0	0	0	3/0	0
6.6	0	0	0	0	3/0	0	1/0	3/0	0
7.0	4/0	5/0	0	0	4/0	0	2/0	3/0	0
7.4	6/0	7/0	0	0	5/0	0	2/0	3/0	3/0
7.8	7/0	7/0	0	1/0	0/7	6/0	2/0	3/0	3/0
8.1	7/0	7/0	0	1/0	7	9/0	2/0	3/0	3/0
9.0	6/2	4/3	1/0	2/0	7	15/0	3/0	3/0	3/0
9.5	3/5	2/5	2/0	3/0	7	16/0	3/0	3/0	3/0
Adult	8	7	10 (9-11)	10 (9-11)	7	18 (15-19)	3	3	3

mm SL	Anal Fin	Dorsal Fin	Left Pelvic Fin	Vertebral Centra		Neural		Haemal		Rakers
				Precaudal	Caudal	Spines	Arches	Spines	Arches	1st Arch
5.5	0	0	0	0	0	0	0	0	0	
6.3	0	0	0	0	0	0	0	0	0	
6.6	0	0	0	0	0	1/0	1/0	12/0	12/0	
7.0	0	0	0	0	0	16/0	16/0	15/0	16/0	
7.4	0	0	0	0	0	25/0	25/0	15/0	19/0	
7.8	0	0	0	0/3	0	25/0	21/4	15/0	19/0	0/8
8.1	0	0	0	0/3	0	25/0	21/4	15/0	19/0	0/8
9.0	6/0	4/0	1/0	0/11	7/2	25/0	18/7	15/0	13/6	0/9
9.5	III,6/0	V,11/0	3/I	0/11	11/4	25/0	4/21	15/0	10/9	0/13
Adult	III,7 (6-8)	XIII,13 (12-15)	I,5	10	16	24	25	15	19	25-30

*Inferior hypural elements include parhypural.

illustrations of Kendall (MS 1982) where he reproduced (p.10) the drawings of these two species by both Moser et al. (1977) and DeLacy et al. (1964). Since my data verifies those of Delacy et al. (1964), the S. caurinus and S. auriculatus figures are apparently reversed in Moser et al. (1977).

Kendall (MS 1982) cataloged the available drawings of premature larvae and larvae at yolk absorption for 44 species of eastern Pacific Sebastes. Among these drawings it is possible to categorize newborn S. caurinus and S. auriculatus into a smaller group based on pigment patterns. Only seven species have both dorsal midline pigment and multiple ventral midline pigment as far forward as the first postanal myomere: S. carnatus, S. auriculatus, S. caurinus, S. maliger, S. rubrivinctus, S. dallii, and S. saxicola. Within this group, S. caurinus is the only species with dorsal pigment forward of the anus. The others resemble S. auriculatus at yolk absorption except that their early dorsal pigment is not quite as extensive. The extent of dorsal pigment may be affected by age at extrusion from the female: ventral pigment appears first during gestation with dorsal pigment complete at birth in S. caurinus and S. auriculatus (Stahl-Johnson MS 1984). Although many of the illustrations in Kendall (MS 1982) are of force-extruded larvae, a combination of dorsal and ventral midline pigment is still a useful character for grouping these species and eliminating other possibilities.

The slight differences in pigment between S. caurinus and S. auriculatus are sufficient to distinguish the larvae of these two species from each other. Presently, only one of the 16 described Sebastes species has pigment patterns that resemble those described here; i.e., S. dallii (Moser and Butler 1981). It is conceivable, however, that still other Sebastes species will be described with similar characteristics; S. maliger is one likely candidate (personal observations).

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THE LARVAL DEVELOPMENT OF *SCHEDOPHILUS MEDUSOPHAGUS* COCCO 1839

(TELEOSTEI, PERCIFORMES)

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INTRODUCTION

Ahlstrom et al. (1976) listed worldwide 8 species belonging to genus *Schedophilus*. As meristics alone permit specific identification beyond doubt for *S.medusophagus*, recent views on the taxonomic status of some of the 8 species and on details of their distributions are not to be discussed here (see e.g.McDowall 1982).
According to Haedrich(1967) most species of *Schedophilus* are oceanic and rare. Consequently, little is known about their biology.Early juveniles of 5 species have been figured by Aboussouan (1983), Ahlstrom et al.(1976),Haedrich (1966), Lütken(1880) and Padoa(1956). A larval *S. medusophagus* of 9.3mm has recently been described by Aboussouan (1983), who included morphometric data for a series 8.5-29.3mm.

The present study deals with a developmental series of larvae of *S. medusophagus*, including the smallest and least developed specimens so far known.Our results are in some details not consistent with Aboussouan's description, the reasons shall be discussed.The restricted occurrence of larval *S. medusophagus* allows additional conclusions concerning the biology of the species.

MATERIAL AND METHODS

From surface plankton(neuston) sampled by German research vessels between 1970 and 1982 nearly all material from the temperate and tropical Atlantic was checked by the authors for the presence of stromateoid fishes.Besides some individuals of other species (under investigation by Karrer),32 larval and early juvenile *S. medusophagus* (8.0 - 37mm) were found in neuston nets (Neu). Disregarding larger specimens, 5 additional juveniles below 50mm were found in catches from the Isaacs Kidd Midwater Trawl (IKMT) or a commercial midwater trawl (MT). All specimens but one came from one single cruise (RV "Anton Dohrn" 92/210). For comparisons two early stages were available from the Copenhagen museum (ZMUC). The origin of material is listed in table 1.
The location of plankton samples analysed and the resulting, rather restricted, occurrence of *S. medusophagus* is shown in Fig.1. For information on the neuston samples we refer to John (1983) and for details on "Anton Dohrn" cruise 92/210 to Tesch (1982).
The identification of early juveniles was based on meristics and corroborated by some morpho-

Table 1: Catches of early stages (< 50 mm SL) of *Schedophilus medusophagus*

Sample No.	Date	Station	Latit.	Longit.	Indiv.	Length(mm)
Neu 168u	27.04.1979	5833	33°02'N	39°33'W	1	37
Neu 183o	02.05.1979	5867	42°00'N	23°32'W	1	13.7
Neu 183u	02.05.1979	5867	42°00'N	23°32'W	1	14.5
Neu 189o	03.05.1979	5875	44°56 N	22°08'W	4	10.9-12.2
Neu 189u	03.05.1979	5875	44°56'N	22°08'W	14	8.0-12.4
Neu 190o	03.05.1979	5877	44°56'N	21°57'W	2	11.2-12.3
Neu 190u	03.05.1979	5877	44°56'N	21°57'W	3	9.5- 9.8
Neu 191o	03.05.1979	5878	44°56'N	21°55'W	2	12.8-16.8
Neu 194u	04.05.1979	5883	44°55'N	17°26'W	2	8.6
Neu 196u	04.05.1979	5885	44°56'N	17°18'W	1	15.5
IKMT 309-II	24.04.1979	5813	29°41'N	49°27'W	1	small juv.
MT 331	27.04.1979	5835	33°04'N	39°29'W	3	33-37
MT 346	29.04.1979	5850	35°24'N	31°53'W	1	42
Neu 37o	09.04.1982	274	35°46'N	31°02'W	1	37
M.W.600 E300	25.06.1931	4197/VII	43°39'N	24°04'W	1	14.9
J 50 107	10.07.1863		43°N	32°W	1	19

Material of the years 1863 and 1931 comes from ZMUC; of the year 1982 from "Meteor" cruise 60. Specimens from 1979 were caught during "Anton Dohrn" cruise 92/210. Neu o refers to the layer 0 - 8cm and Neu u to 9 - 24cm. The other abbreviations are explained in the text.

logical characters (see below). The development of habitus and pigmentation was then traced backwards to the smallest identifiable specimen of 8.0 mm. Few unidentified larvae remain, they do not seem to belong to Stromateoidei. Fish eggs were left in the plankton samples and are not considered.
The descriptions are based on larvae preserved in about 4% formaldehyde solution for about 4 years. The juveniles and the ZMUC specimens were, after preservation in formaldehyde, kept in ethanol. Some specimens were cleared and stained (after Clothier 1950). For definitions see Ahlstrom et al. (1976).

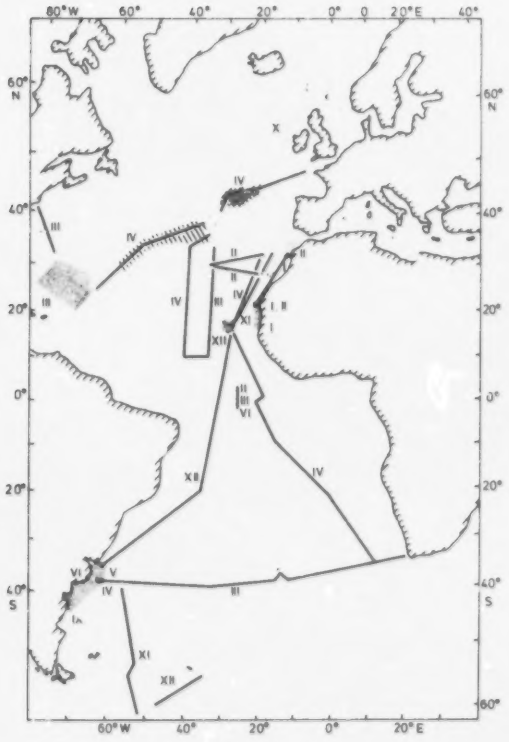

Fig.1:The scheme of plankton sampling and occurrence of young *Schedophilus medusophagus*. Lines denote transects, shaded areas station grids. Roman numerals indicate the months of sampling.Hatched: Occurrence of juveniles 20 - 50mm. Cross-hatched Occurrence of larvae.

IDENTIFICATION
So far, larvae were completely unidentifiable until the fin ray counts tended to become stable at lengths above 12.5mm. Counts of D 48 - 52 and A 29 - 32 pointed to *S. medusophagus*, as the larvae of some other species with similar fin ray combinations were known. These values in combination with a total of 25 vertebrae is rather unique, not only among Stromateoidei (Haedrich 1967). Some doubts resulted from the rather slender body unusual for early stages of Stromateoidei as far as they are known (except in *Tetragonurus*), though the largest specimens here already had the stromateoid "face". Identification was corroborated by the following characters: In two larvae the anterior two or three dorsal elements are apparently weak spines. There are 7 branchiostegal rays, the margin of the preopercle is serrate. The positions of developed fins correspond to those described for this species.
A more thorough examination showed, that fin ray meristics could be traced back to specimens of down to 11mm by using pterygiophore counts. The developmental series down to 8.0mm was composed of a representative sequence of lengths while not revealing any obvious changes in other characters.

DEVELOPMENT
The smallest specimens were still in the preflexion or, mostly, flexion stage (8.0 - 9.5mm NL). Postflexion stages occurred from 9.2mm onwards. Earliest stages had a maximum body depth of approximately 25% of NL. The change of length measurement during flexion from notochord length to standard length in specimens between 9.2 and 9.5mm resulted in an apparent increase in relative depth (Fig.2).

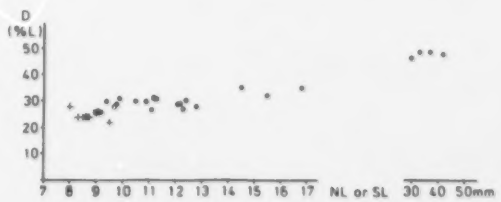

Fig.2: The greatest body depth of *Schedophilus medusophagus* in relation to length. Crosses = notochord length NL. Dots = standard length SL.

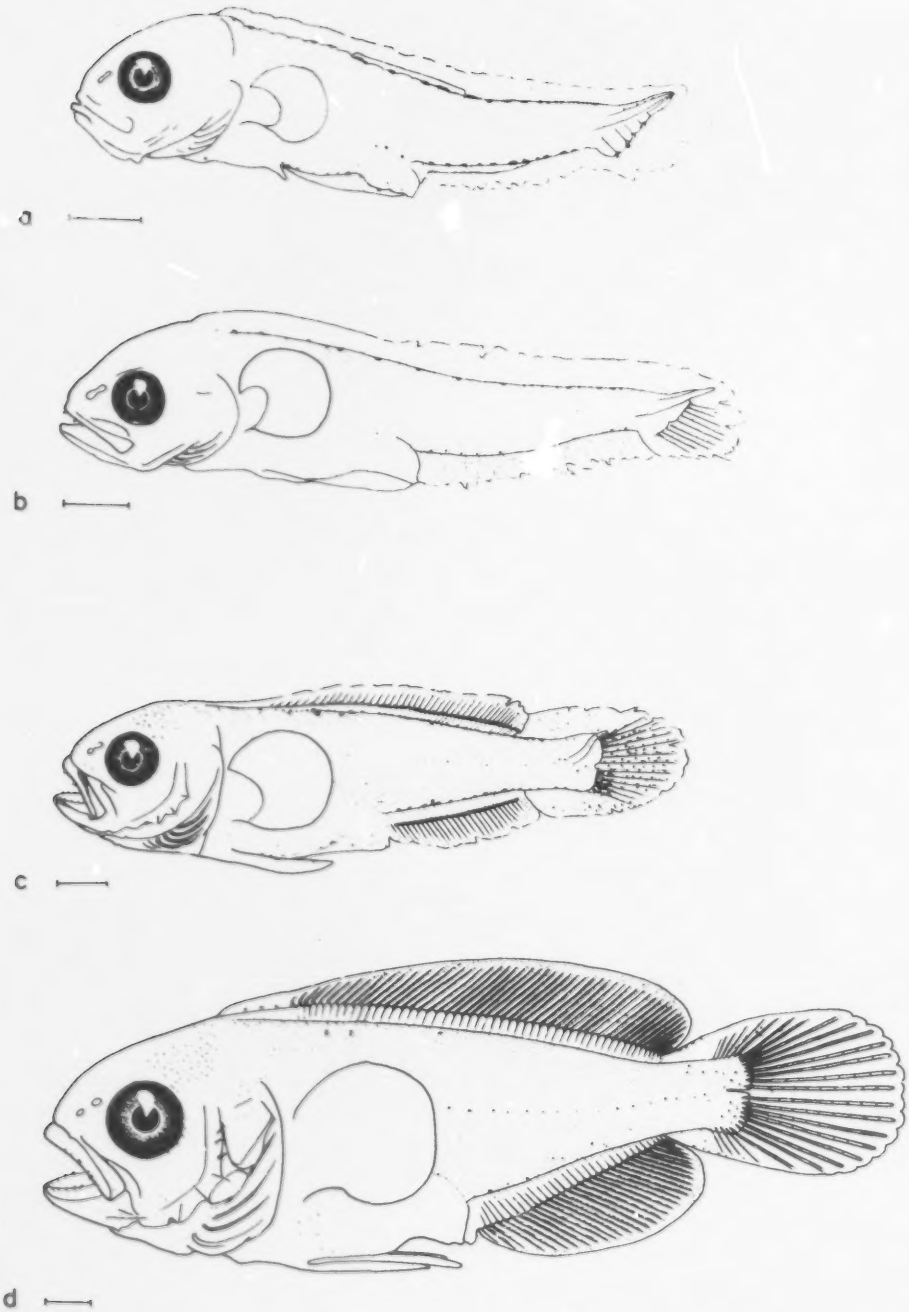

Fig.3: Larvae of *Schedophilus medusophagus*. Length scales equal 1.0mm.
a) 8.6 mm NL. b) 9.5 mm NL. c) 12.1 mm SL. d) 16.8 mm SL.

Relative depth then stabilized at about 30% for the length range 9.5 - 13mm. These animals were still very different from the smallest described juveniles of the genus *Schedophilus*. Larger larvae resembled them slightly more, as far as relative body depth and the typical appearance of the head are concerned (D 30 - 35% of SL, compare e.g. Figs.3d and 4). Early juveniles (which had obviously shrunk somewhat in ethanol after brief preservation in formaldehyde) had relative depths of about 47% (Fig.2). Allometric growth is the rule in stromateoid fishes (e.g. Haedrich 1967). While the values for the smallest and largest specimens investigated correspond broadly with the data given by Aboussouan (1983), his data for the length range 12 - 15mm are distinctly higher (34 - 44%), and two additional ZMUC specimens kept in ethanol (14.9mm and 19mm) showed similar relative depths of 41 and 43%, respectively.

In the smalllest specimen found (8.0mm), no ossification was observed in the vertebrae, but caudal rays were developed and could be stained (6 dorsal, 8 ventral rays). The pectoral fin had 8 and the ventral fin 3 rays. No rays were visible in the dorsal and anal fins, but developing pterygiophores could be traced. Differentiation of the anal fin starts in the anterior part, except for the first and second rays, which begin to develop at about 11mm. Differentiation of the dorsal fin starts at approximately the first third of its final relative length and advances into both directions. Differentiation caudad proceeds faster than craniad. Generally, development in the anal fin is more advanced than in the dorsal fin.

At length above 9mm the exact number of vertebrae can be counted in polarized light, though ossification has not yet started in all elements. Some dorsal and anal rays appear, but are fewer in number than pterygiophores in specimens up to 13mm length. Developing pterygiophores become visible fairly well in polarized light, when the mucus covering the entire body is removed from the fins. In the length class 8 - 8.9mm 12 - 22 dorsal and 5 - 19 anal pterygiophores were found. In the following group up to 9.9mm the counts were 24 - 43 and 9 - 26, respectively. The anal fin with 26 pterygiophores was the most advanced and showed already 21 rays. A stained specimen of 9.9mm length had seven branchiostegal rays. There were 20 caudal rays, most neural and haemal spines were ossified (to vertebra 23 or 22, respectively). A specimen of 9.3mm figured by Aboussouan (1983, Fig.13a), however, appears to be completely differentiated. Except for pigmentation, this specimen seems to agree better with our 12 mm size class. While for the following length class 10 - 10.9mm the counts were in the upper range of the previous class, the group 11 - 11.9mm already approached definitive values with 47 - 49 pterygiophores in the dorsal and 28 - 30 in the anal fin, only one or two of the anterior and posterior pterygiophores did not yet have rays. The first anal pterygiophore became visible in all three specimens of 11.2 and 11.3mm. Larger animals had definitive numbers of supporting elements in these fins, occasionally even showing 2 or 3 spines for the cranial part of the dorsal fin. The development of a second ray on the last pterygiophore was barely visible in the anal fin of a specimen of 16.8mm and distinct in both dorsal and anal fins of the largest specimen caught in neuston nets (37mm).

The specimen of 17.3 mm figured by Aboussouan (Fig.13b) also appears to be more advanced than our larva of similar size. From the above given comparisons on relative body depths, including the ZMUC specimens, we suspect much higher longitudinal shrinkage for animals preserved in ethanol. Assuming an original relative depth of 35% for the ZMUC specimens, their standard lengths "standardized to formaldehyde preservation" might have been 17.4 and 23.4mm. In fact, development of the smaller individual agrees well with our described 16.8 mm specimen; the larger one is definitely an early juvenile similar to Fig.13b by Aboussouan. We conclude, that body lengths of larvae and early juveniles preserved in ethanol are only about 85% of the lengths of formaldehyde material in the same stage of development.

The dentation of the preopercle of large larvae (Fig.3d) agrees with descriptions of juvenile *S. medusophagus* (Haedrich 1966; Lütken 1880) or juveniles of other *Schedophilus* (Ahlstrom et al. 1976; Padoa 1956). This character, however, was not completely consistent and even less conspicuous throughout the larval phase. Spines at the preopercle were not visible in specimens up to 9.5 mm. Three triangular spines were inconspicuous in specimens 9.7 - 9.9mm. These spines become somewhat more elongate and increase in number with increasing body length (6 spines at 12 mm and above, stained specimens might reveal more). Generally, however, only 2 of these spines, namely those closest to the edge of the preopercle and pointing caudo-laterad, project above the skin covering the preopercle. Occasionally all spines are hidden.

Fig.4: A juvenile *Schedophilus medusophagus* of 37mm standard length.

PIGMENTATION

In preserved larvae the general colour is a light greenish yellow. One specimen (15.5mm, identical preservation) differs in showing a more rose-brown colour, smallest specimens appear whitish yellow.

All individuals have rather inconspicuous patterns of minute to small light brown melanophores. Their visibility appears to be more dependent of the presence or absence of mucus and preservation than of ontogeny, except for midlateral melanophores and pigmentation on the head.

Dorsally the head is generally covered by minute dots, being scarce in number and inconspicuous up to 9.5 mm length. Above 10 mm, the dots become numerous, extending frontally and ventrally. At lengths about 11 mm very light pigmentation includes the jaws and lower jaw angle.

Mediolateral pigmentation, consisting of a sequence of minute dots beginning at about the first third of the body and extending to the caudal peduncle, develops at about 11 mm. These dots number generally one per myotome (occasionally two in the posterior part).

Among the most consistent and relatively conspicuous features are the series of internal stellate pigment dots along the dorsal and ventral contours of the body. Compared with the dots discussed above, these are relatively large and retreat deeper into the body in larger larvae. Even in the smallest specimens found, the dots occur along the later bases of dorsal and anal fin. The anal series seems to extend craniad, forming the median dorsal peritoneal melanophores, occasionally the dots may spread over a wider part of the peritoneum. The dorsal series reaches the occiput. Its anterior 3 to 6 dots may become rather distinct. Caudad both series reach the later caudal peduncle. Though the anal series is generally less distinct than the dorsal one, this may be different for its hindmost part. In specimens larger than 11mm, these mentioned series are supplemented by paired sequences of smaller, superficial dots along the pterygiophores. Though irregularly spaced, they sometimes appear to form a continuous line. Midventrally a rather straight series of dots exists along the gut throughout ontogeny. It may reach from the isthmus to the anus, more frequently it occurs from about the ventral base caudad to the anus. In one case this series was not found. Some dots may be scattered close to the anus.

Pigment is generally present at the end of the caudal peduncle, at the remains of the primordial fin above and below the peduncle and at the anterior part of the caudal fin. The ventral fins become lightly pigmented at lengths of 10.9mm. The pigmentation on membranes of dorsal and anal fins is generally present, but invisible below the mucus. Both figures by Aboussouan agree generally with this description. Though we have to take into account the above mentioned exception, and the larger ZMUC specimen is also darker, we generally consider the pigment patterns to be less distinct than might be concluded from Aboussouan's figures. Particularly we did not observe the lateral blotches of scattered melanophores shown in his Fig.13a.

ZOOGEOGRAPHICAL AND ECOLOGICAL COMMENTS

All neuston sampling was done with comparable, mostly identical methods. The mean distance between stations did not exceed 50 nautical miles; in the area 10°N - 33°N/27°W - 33°W distances were greatest with 100 miles. In station grids hauls were more closely spaced. For the seasons actually sampled, the limited occurrence of early stages must therefore be of zoogeographical significance. Larvae (for details see table 1) occurred distinctly northeast of the findings of juveniles (Fig.1), thus they agreed closer with the previous known distribution of adults (see Templeman & Haedrich 1966, "*Centrolophus britannicus*"). The specimens investigated by Aboussouan (1983) and the smaller ZMUC specimen come from the area of our larvae catches. The early juveniles figured by Haedrich (1966, no length stated) or from ZMUC are reported from 41°20'N 29°20'W and 43°N 32°W, respectively, i.e. between the areas of larvae and juveniles. We did encounter several animals >300mm at the positions where larvae were caught. As during the "Anton Dohrn" cruise most efforts in both neuston sampling and trawling were about evenly distributed regionally, the differing occurrences of length classes may be an effect of drift. The larvae were caught in an area where part of the North Atlantic Drift turns into the Portugal Current. The early juveniles, during the time of sampling, occurred in a zone of variable currents situated between the North Atlantic Drift and the Canary Current. For the months preceding the catch, however, charts of surface currents (Dhi 1967) do not rule out a link between both areas of occurrence.

Table 1 suggests that larvae occur at least throughout the months April to June and probably also earlier in the year.

All positive neuston catches were twilight or nighttime samples. The lower net sampling 9 - 24 cm yielded 22 of the total of 32 specimens caught by the neuston sampler. This suggests, together with the general appearance (body laterally compressed, only slightly pigmented), that early stages of *S. medusophagus* are not truly neustonic. In all positive catches the presence of medusae, together with other gelatinous zooplankton, was recorded, but this holds true also for many of the negative stations.

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